ANALYSIS OF THE EFFECT OF CENTRALIZING MANAGEMENT OF MOBILITY READINESS SPARES PACKAGE ASSETS

THESIS

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AFIT/GLM/ENS/01M-12

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THESIS

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Abstract

Current Air Force supply doctrine requires the management of large numbers of spare parts in Mobility Readiness Spares Packages (MRSPs). The MRSPs are usually designed to support deployed aircraft for the first 30 days of a conflict, and can be quite large. When units from several bases deploy to the same operating location, they each bring their full MRSP. This results in a large logistics footprint that may be reduced by taking a system-level approach.

This thesis examined the impact of centralized MRSP management on kit size and cost. The Aircraft Sustainability Model (ASM) computer program was used to evaluate MRSPs for F-15C, C-17A, and B-52H aircraft deploying in both the traditional manner and with customized MRSPs from a centralized facility.

The results of the ASM analysis indicate there is a significant cost and size savings when MRSPs are customized for the total number of aircraft deployed to a region of conflict. While the size of the savings varied between aircraft and flying hour profiles, MRSPs from the centralized facility always provided the same level of support for less cost. The results show the Air Force could release spare parts locked up in standardized MRSPs and relieve some of the current spares shortages without degrading unit readiness.

ANALYSIS OF THE EFFECT OF CENTRALIZING MANAGEMENT OF MOBILITY READINESS SPARES PACKAGE ASSETS

I. Introduction

Background

The United States military is facing a world that is changing more rapidly than ever before. With the Cold War over and the elimination of the Soviet threat, America's armed forces are no longer able to point their collective fingers and say "There's the enemy, let's start planning." Congress and the American people have proclaimed a "peace dividend" and have scaled back funding of defense programs and budgets. At the same time, they have set the standards to which the military must size itself and have called for ever-increasing involvement in military operations other than warfare (MOOTW). These small-scale contingencies and humanitarian relief efforts actually task our forces more than a major theater war (MTW) ever would (AMSP: 1.4.2).

An aging fleet of heavy airlift aircraft, primarily the C-141 Starlifter, has put new constraints on the Air Force's ability to deploy forces anywhere in the world at a moment's notice. In a June 2000 report, the GAO stated that the Air Force could not meet the requirements for a two major theater war scenario because there is an estimated

29% shortfall in cargo airlift capacity (GAO report, 2000: 5). The C-17 Globemaster III is the replacement for the C-141. While it carries substantially more cargo than the C-141 and can land on unimproved runaways, Congress has funded only 120 C-17 aircraft to replace 266 C-141s. The theoretical airlift capacity remains about equal, but the loss of flexibility inherent in possessing only half the airframes means the remaining aircraft must be used more efficiently.

Mobility Readiness Spares Packages

Most conflicts in the world occur far from peacetime operating locations. When Air Force units are called up, a massive logistics effort by air, ground, and sea moves the units into forward locations where they must be supported until the conflict is resolved. The Air Force supports the initial deployment by sending spares in standardized containers. The initial cache of spares is designed to support the deployed aircraft until a resupply pipeline can be established. In the past, this time period was assumed to be 30 days at the most. In reality, advances in transportation technology and the rise of rapid air transport have reduced the pipeline setup time significantly.

Current Air Force supply doctrine requires the management of large numbers of spare parts in Mobility Readiness Spares Packages (MRSPs). The kits, as they are also known, are usually configured to support a given number of aircraft for a set amount of time, usually 30 days. They are designed with the assumption that no resupply takes place during the first 30 days. The packages can be quite large, with between 15 and 20 conexes (large containers for parts) plus wheel and tire pallets.

There is a general belief that too many parts are stored in the MRSPs. The author witnessed this during Operation PHOENIX SCORPION IV (Air Mobility Command's support of the deployment of US forces to the Persian Gulf), in which a large C-17 kit was deployed for nearly a month and had only a few parts issued during the entire operation. The resulting large logistics footprint places a strain on already overburdened airlift capacity, so the current direction of research is to determine how to reduce the number of parts necessary for the initial deployment. The base-level maintenance, inventory, and personnel support requirements are also significant when maintaining large numbers of assets ready to deploy in less than 24 hours.

MRSPs possess a higher fill priority than regular peacetime operating stock (POS) assets at base level. When a reparable asset arrives on base, the base supply system checks for requirements and fills them based on the priorities assigned to the backorders. Outstanding backorders for the maintenance organizations are satisfied first, then MRSP backorders, and finally POS requirements (AFM 23-110: 2001, V2P2C9.40.3.4). Often, there are not enough assets to meet all the requirements due to the previously mentioned funding shortfalls. The result is that bases are forced to "live out of the kits," and base-level POS requirements remain empty. The situation causes constant shuffling of assets between the MRSP location and the flightline delivery location, and increases the probability of inventory inaccuracies and longer delivery times.

Reparable Asset Pipeline

The Air Force uses a multi-echelon inventory system to manage reparable assets. A multi-echelon system is one in which assets are warehoused in a hierarchy of locations.

Reparable assets are those items that are economically feasible to repair rather than dispose of when they become unserviceable through use. In general, reparable assets are expensive and thus are in much shorter supply than consumable items. The Air Force attempts to manage reparable assets in a way that balances inventory levels with desired aircraft availability levels for a set budget.

Reparable assets enter the Air Force inventory through acquisition channels, and are managed by depots located throughout the U.S. The depots support bases with aircraft that use the items by allocating the assets in a way that maximizes total system aircraft availability. Assets may be stored at the depot only, at bases only, or in a combination of depot and base supply stock. Unserviceable assets are returned to the depot for repair or disposal. This return loop makes the model a cyclic one, where inventory is not lost or renewed, except in extreme cases where an asset becomes economically unfeasible to repair. The demand in cyclic reparable models is driven by failure and repair events (Díaz and Fu, 2000: 7).

Items of Evaluation

The individual indicators Air Force managers examine are MRSP fill rates, Not-Mission-Capable-Supply (NMCS) rates, and aircraft availability. A fill rate is expressed as a percentage of the parts in the MRSP compared to what the MRSP is authorized to have. There are no mandated lower limits on fill rates during peacetime, but resupply to the kits is always a higher priority than regular operating stock at a base. The NMCS rate is the percentage of aircraft that are grounded due to lack of a specific part or parts.

Aircraft availability is the final measure of all logistics activity, and is the percentage of aircraft ready to fly and fight (Larvick, 2000: 13).

MRSPs are usually "robusted" before deployments, meaning they are inventoried and then stocked to the highest fill rate possible using parts from other, non-deploying kits. So, while the average fill rate during peacetime may be low, they are usually deployed with a higher fill rate than normal. Fill rate should not be the only measure of MRSP effectiveness because there are times when critical assets are not available in the kit and the aircraft may be grounded for parts, even if the MRSP has a 99% fill rate (Larvick, 2000: 13). For this reason, the newer models used for analyzing kit effectiveness use aircraft availability as the final measure of customer service.

Issue

Several methods of reducing the size of MRSPs have attracted attention. They include reducing the MRSP resupply pipeline time, improving in-transit visibility, and establishing Consolidated Intermediate Repair Facilities (CIRFs). The 30-day configuration is a Cold War era paradigm that is currently being reevaluated. The question many supply mangers are asking today is what is the most effective way to allocate spares to Mobility Readiness Spares Packages (MRSPs or kits) supporting AEF deployments? This thesis will address a new answer: that of centralizing the kits at regional centers and then building up focused MRSPs when deployments occur. The following figures illustrate the differences between the current and proposed modes of operation:

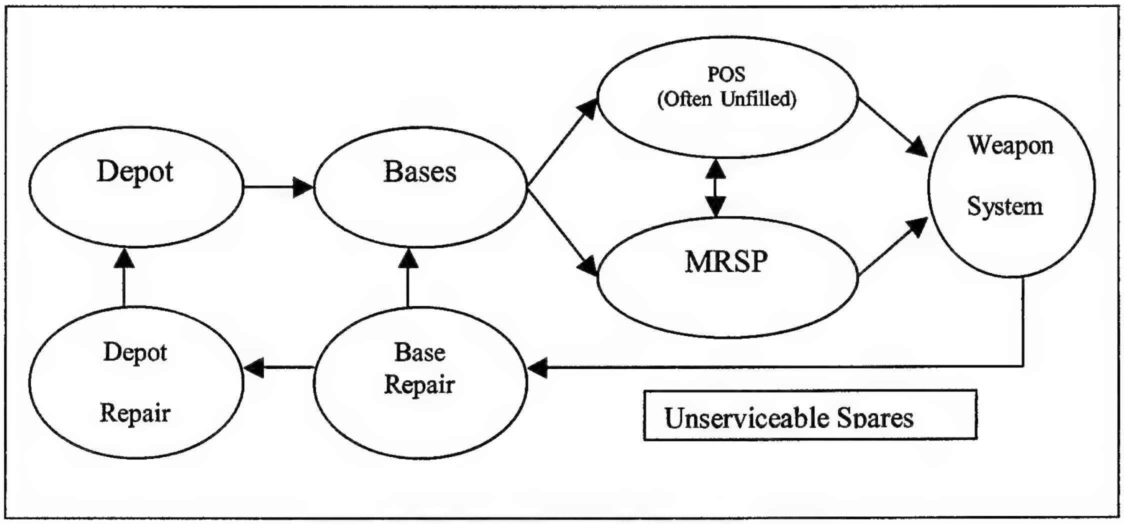

Figure 1: Traditional MRSP Management Model

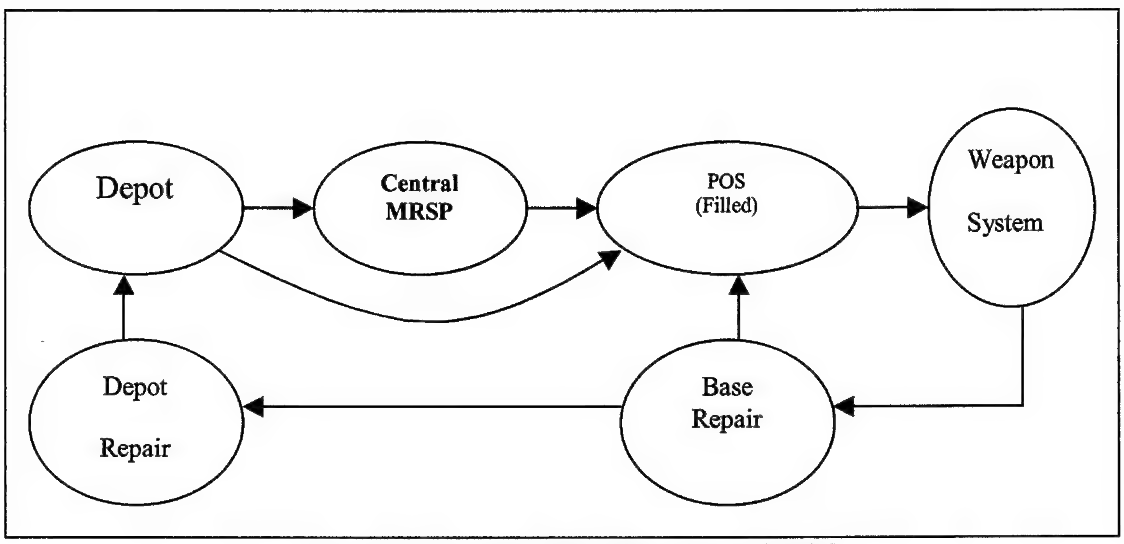

Figure 2: Proposed MRSP Management Model

The basic premise behind the concept is simple: if multiple squadrons of identical aircraft deploy to the same Forward Operating Location (FOL), they would normally take a standard MRSP from each base. The FOL would then have multiple squadrons of aircraft with multiple full MRSPs. For example, if two 24-aircraft squadrons from different bases deploy to the same FOL, they would take two full MRSPs in support. During the Gulf War in 1990-91, a 24-plane fighter squadron required the equivalent of

20 C-141 loads to deploy (Snyder, et al, 1998: 16). The MRSP is not the total load, but is a significant portion of the footprint. Forty C-141 loads would be required to deploy the hypothetical two squadrons. When they arrived at the FOL, the number of hours it would take to set up and the amount of storage space the MRSPs require would be considerable.

The number of aircraft at deployed locations today is small; several 6 to 12 aircraft units deployed throughout the theater are becoming common. A CIRF is set up at a central point and a main support warehouse is established to feed parts to the dispersed units. This is a change from the large, 50+ aircraft deployments the Air Force has historically deployed.

Research Question

This thesis will determine what, if any, savings can be gained from centralized management of MRSP assets. The premise behind this statement is that of economies of scope: a single MRSP designed to support 48 aircraft should be smaller than two MRSPs designed to support 24 aircraft each.

Investigative Questions

The following investigative questions have been developed to direct the research and help answer the thesis question.

1. How does the Air Force currently determine MRSP requirements?
2. What model/models are used to build up MRSPs?
3. What are the relevant theories about centralized inventory management?

4. Are any other military services using centralized management to reduce costs and/or logistics footprint?
5. What is the effect of customized MRSP creation at a central location?

Scope

The research will examine only the effects of centralizing the management of MRSPs for F-15C, C-17A, and B-52H aircraft. No reduction in pipeline times will be assumed for the scenarios. That research is an ongoing effort by numerous others and will not be addressed here. The thesis will not discuss the political ramifications of removing local base MRSP assets. Base operations routinely use MRSP assets for day-to-day flight operations, and removing them, even for the purpose of returning more assets to regular POS, would need higher headquarters' approval. This thesis will only evaluate the potential savings that may result from such a decision.

Summary

This chapter has provided a general introduction to the topic and defined the research questions to be answered in the study. Chapter two is a literature review, and will further explore previous work and explain some concepts vital to the understanding of the thesis. Chapter three will explain the methodology used and the operation of the Aircraft Sustainability Model (ASM). Chapter four will discuss the results and any conclusions to be made. Finally, chapter five will wrap up the thesis with a final discussion and any further research suggestions.

II. Chapter 2--Literature Review

Military forces throughout the ages have recognized that an army without good logistics support is destined to fight a very short war. This literature review will provide some background needed to understand the ideas behind the thesis. The review will first discuss the progression of inventory management techniques from simple ones to more complex dynamic, multi-echelon models. It will then examine MRSP characteristics and factors that affect the ASM computations. It will finish with a discussion of centralized inventory management theory and a look at a Navy program that uses centralized assets to improve support.

Inventory Management Techniques

The task of reducing the amount of inventory necessary to achieve a desired level of availability has prompted many studies. This section will start with the most basic methods and models and proceed to the more complicated and recent models. The relevance of mathematical models to this study precludes the inclusion of other methods such as neural networks and queuing models.

Simple Pipeline. The simple single base repair pipeline consists of four components through which the reparable asset passes. When a part on an aircraft fails, it is removed and sent to through the base repair cycle process to the repair shop. At the same time, a serviceable part, if available, is sent to the aircraft for installation. Figure 3 shows this simple model and the path a part takes through it.

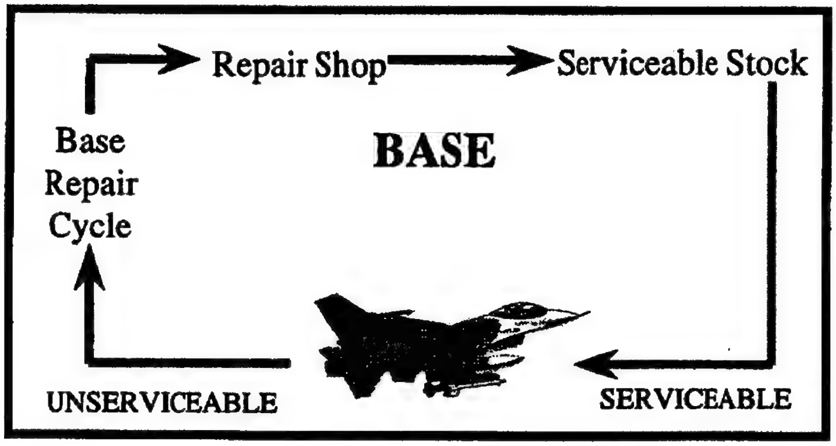

Figure 3: Simple Pipeline (Arostegui, 2000)

For this model, there are two major factors we are concerned with. The first is the Daily Demand Rate (DDR), and the second is the Repair Cycle Time (RCT). The DDR is simply the number of demands an item receives per day. For example, if the base shows the number of orders for a quarter is 65, then the DDR for the part is 65/120, or .542. The repair cycle time is determined by the base repair facility, and may be different for each part. In the simple model, no parts are ever condemned (the system is *conservative*). In addition, we assume every part is essential, so a part missing downs the aircraft. No cannibalization activities are permitted, so each aircraft has only one part removed.

With the model defined, we now turn to calculating the number of spare parts we expect to be in the pipeline on average. This is simply the DDR multiplied by the RCT. If we assume the RCT is five days, then the Pipeline Quantity (PLQ) is .542*5, or 2.71 parts in the repair pipeline at any given moment in time. This model is very simplistic, and does not represent the majority of inventory systems operating in the real world. It does provide a good starting point from which to build a suitably applicable model. The vast majority of inventory systems are multi-echelon systems, with multiple levels of inventory.

Multi-echelon Networks. Clark states that multi-echelon theory is "concerned with a variety of inventory problems involving two or more interrelated supply or production facilities (Clark, 1972: 621)." Many inventory systems in the civilian sector involve the flow of consumables from factories to distribution centers and then on to points of consumption. This common type of network is referred to as an "arborescent" or inverted tree structure (Clark, 1972: 622).

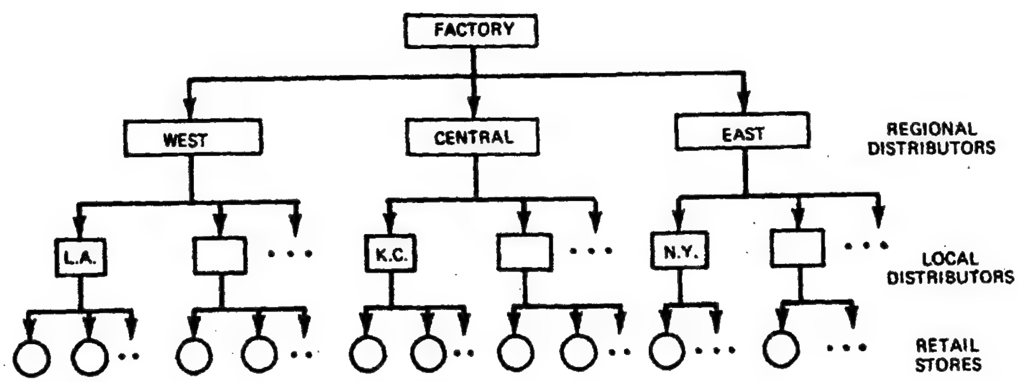

FIGURE 1. Distribution system for a grocery product

Figure 4: Arborescent Structure (Clark: 1972)

It is important to note that the above structure may change for every item. A different factory may produce the item, or an entirely different distribution network may be in place.

The levels within the arborescent structure are generally referred to as echelons, so any network with numerous levels is called a multi-echelon network. While this works for consumable items with no return loop, Clark argues that the nomenclature is too restrictive to be used in a general sense (Clark, 1972: 622). However, the general trend in the literature suggests that most authors are comfortable with using the term "multi-echelon" when discussing any network with more than one level.

A simple Air Force example of a multi-echelon network involves the addition of a depot to our first model, as shown in Figure 5 below:

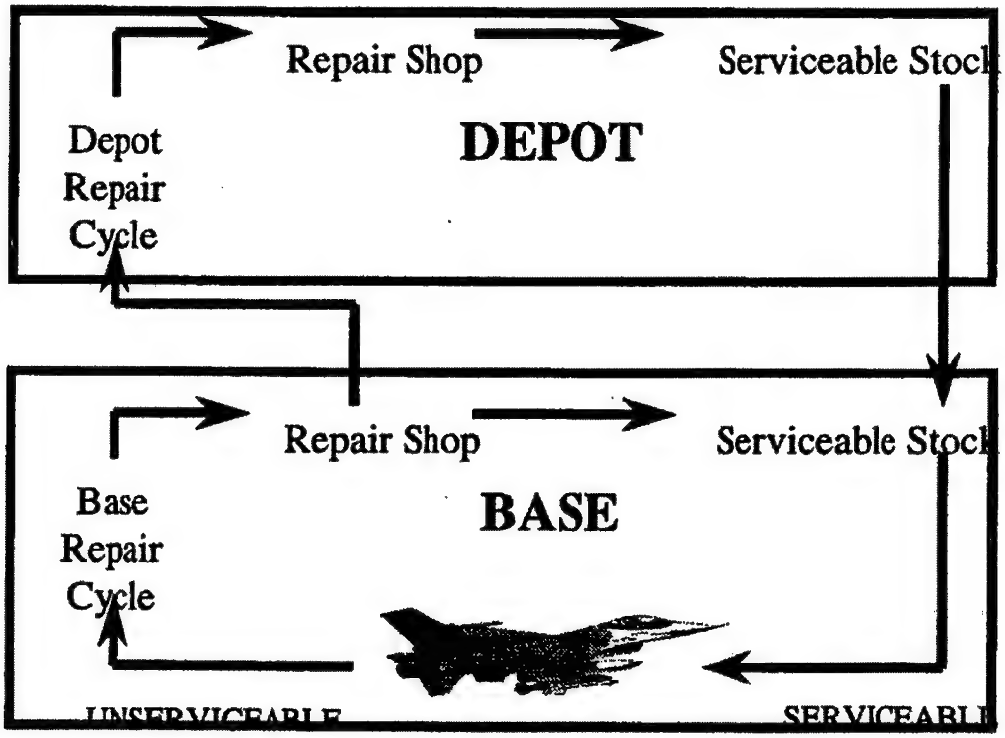

Figure 5: Simple Multi-Echelon Network (Arostegui, 2000)

In addition to the base repair pipeline, the network now has a repair and resupply pipeline to and from the second echelon, the depot. Items that cannot be repaired at the base repair shop are sent into the depot repair cycle. The time it takes an item to move from the base to the depot is called the retrograde time (RET). The depot repair shop will take some amount of time to repair the item, which is the depot repair time (DRT). At the same time an item leaves the base, the base orders a replacement from the depot using an (S-1, S) inventory model where a part is ordered for every unserviceable part that leaves the base. If the depot has assets the time it takes for the order to arrive at the depot, be processed, and then be shipped to the base is known as the order and ship time (OST).

To determine the amount of stock in the pipeline for the above model, the percent base repair (PBR) needs to be calculated. This is simply the number of items repaired this station (RTS) divided by the total number of demands for the item. The base repair cycle quantity is then:

$$RCQ = DDR \times RCT \times PBR \quad (1)$$

The OST quantity is simply the DDR multiplied by the number of demands sent to the depot (1-PBR) times the OST:

$$OSTQ = DDR(1 - PBR) \times OST \quad (2)$$

The depot RCQ is a modification of the base RCQ that adjusts for the percent of items sent to the depot:

$$DRCQ = DDR(1 - PBR) \times DRT \quad (3)$$

The retrograde pipeline quantity is found with the following equation:

$$RPQ = DDR(1 - PBR) \times RET \quad (4)$$

Finally, the average number of items in the total pipeline (the total system requirement (TSR)) at any given time is the sum of the individual pipeline quantities:

$$TSR = BaseRCQ + DepotRCQ + OSTQ + DRCQ + RPQ \quad (5)$$

The model above can be made even more complex by adding condemnation rates or other variables to the mix. One item to note is that the quantities used are generally averages taken over several periods, and usually vary over time. To compensate, a safety level is usually established using some pre-specified formula. In addition, this model must be applied to every item in the inventory and seeks only to optimize the service level of a particular item instead of the entire system. For that, a system-wide multi-echelon inventory management technique must be used.

Types of Multi-echelon Models. There are many ways of formulating multi-echelon models in response to the different data types and behaviors of the network being modeled. Clark outlines six dichotomies that he says help distinguish the various types:

Table 1: Types of Multi-echelon Models (Adapted from Clark, 1972)

Deterministic	**Stochastic**
External demands at each activity are known in advance	Demands known within a given probability distribution (or conditional distribution)
Single-Product	**Multiple-Product**
Deals only with one product at a time, ignores possible interactions	Deals with more than one products simultaneously, attempts to optimize based on one or more criteria such as budget
Stationary	**Nonstationary**
Parameters defining external demands considered to be independent of time	Parameters defining external demands may change over time
Continuous Review	**Periodic Review**
Opportunities to review stock position and implement policies occur continuously	Opportunities to review stock position and implement policies occur at discrete points
Consumable Product	**Reparable Product**
All issued items are permanent losses to the system	Some or all of the items issued are regenerated as items that may be reissued
Backlog	**No Backlog**
Unsatisfied demands are retained and satisfied from later resupply	Unsatisfied demands are not retained and are assumed lost to the system

Using Clark's criteria, the models previously examined are deterministic, single-product models with stationary demand. They are subject to continuous review, deal with reparable items only, and may or may not consider backorders. In a more recent article, Díaz and Fu uphold Clark's taxonomy, substituting the terms "cyclic" and "acyclic" for reparable and consumable types of flow, respectively (Díaz and Fu, 2000: 8).

Probabilistic Models. It is generally assumed (though not usually specifically stated) that a system-perspective model performs better than a single-item model. In 1968, Sherbrooke published an article in *Operations Research* titled "METRIC: A Multi-Echelon Technique for Recoverable Item Control." Díaz and Fu call METRIC "the most

influential model by far (Díaz and Fu, 2000: 9)." They state that METRIC was interesting for two main reasons. The first was that Sherbrooke used exchange curves of system availability versus investment value of spares, instead of finding a single "optimal" value. The second reason is that he allocated spares based on a global basis. Further research by Muckstadt and Thomas showed that simple multi-echelon models such as METRIC do yield better results than a simple naïve local optimization (Muckstadt and Thomas, 1980: 494). This section will provide an overview of the METRIC model and some of the more advanced developments based on METRIC.

Díaz and Fu (2000, 10) describe key relationships they say form the basis for analyzing multi-echelon models for repairable items. They break down the process into three general steps:

1. Determine the distributions for the parts population through the various components of the system
2. Combine the distributions to determine backorder distributions
3. Determine availability from the backorder distributions

In addition, they consider a system of a single base and a single depot, each with a specific target of spares. They represent the system as a network of discrete elements, including:

1. a stock of working-level parts (installed parts on aircraft)
2. a base-to-repair facility pipeline for failed parts
3. a repair facility
4. a depot storage facility stocking more spares

5. a depot-to-base pipeline

6. a base storage facility stocking spares (base supply)

Using this basic framework, Sherbrooke developed the METRIC model, which was quickly adopted by the military as a means of maximizing aircraft availability at a given budget level. We now discuss the METRIC model in detail.

METRIC. METRIC is an extension of the single-site model with two echelons of repair and resupply. It adds multiple bases to the system. It is a single-indenture model, which means that each part is a line replaceable unit (LRU) with no shop replaceable units (SRU). This simplifies the model but is not especially accurate because many reparable parts have smaller reparable parts installed on them (SRUs), and a lack of SRUs can significantly impact repair times. METRIC is a stationary, stochastic model that addresses multi-echelon, multi-item, multi-location systems. Its goal is to minimize expected backorders (EBO) (Arostegui, 2000).

METRIC uses several assumptions to make the computational effort less tedious. For base repairs, the decision to repair does not depend on the stock levels or workload. This means that if the base has the capability to repair a failed item, it will do so. Maintenance workload is not a factor. In terms of resupply, METRIC assumes bases receive assets from the depot only. No lateral resupply from other bases is allowed. This assumption makes sense because stock replenishment actions from the depot should be routine. Lateral resupply involves additional costs that are not easily incorporated into the model, and in practice lateral resupply is only a small fraction of the bases' business. The stockage policy at every echelon is an (S-1, S) policy (also known as a one-for-one policy). There is no batching of units for repair and no batching of resupply requests.

Because the items exhibit low annual demand and high unit cost, the classic economic order quantity (EOQ) formula would yield a recommended order quantity of one. Because the model is stationary, METRIC assumes that the number of aircraft operated and their flying hours will remain fairly constant over the near-term. METRIC also assumes the system is conservative and therefore does not account for condemnations of assets.

One very important aspect of the METRIC model is that it minimizes the expected backorders for the entire system. Therefore, a base backorder lasting 10 days is treated just a seriously as 10 one-day backorders. This may or may not be a good characteristic, depending on the commander's perspective. Is it better to have 10 aircraft down for one day, or one aircraft down for 10? The final assumption for METRIC is that demand data from different bases can be pooled. Figure 6 shows the METRIC model in schematic form.

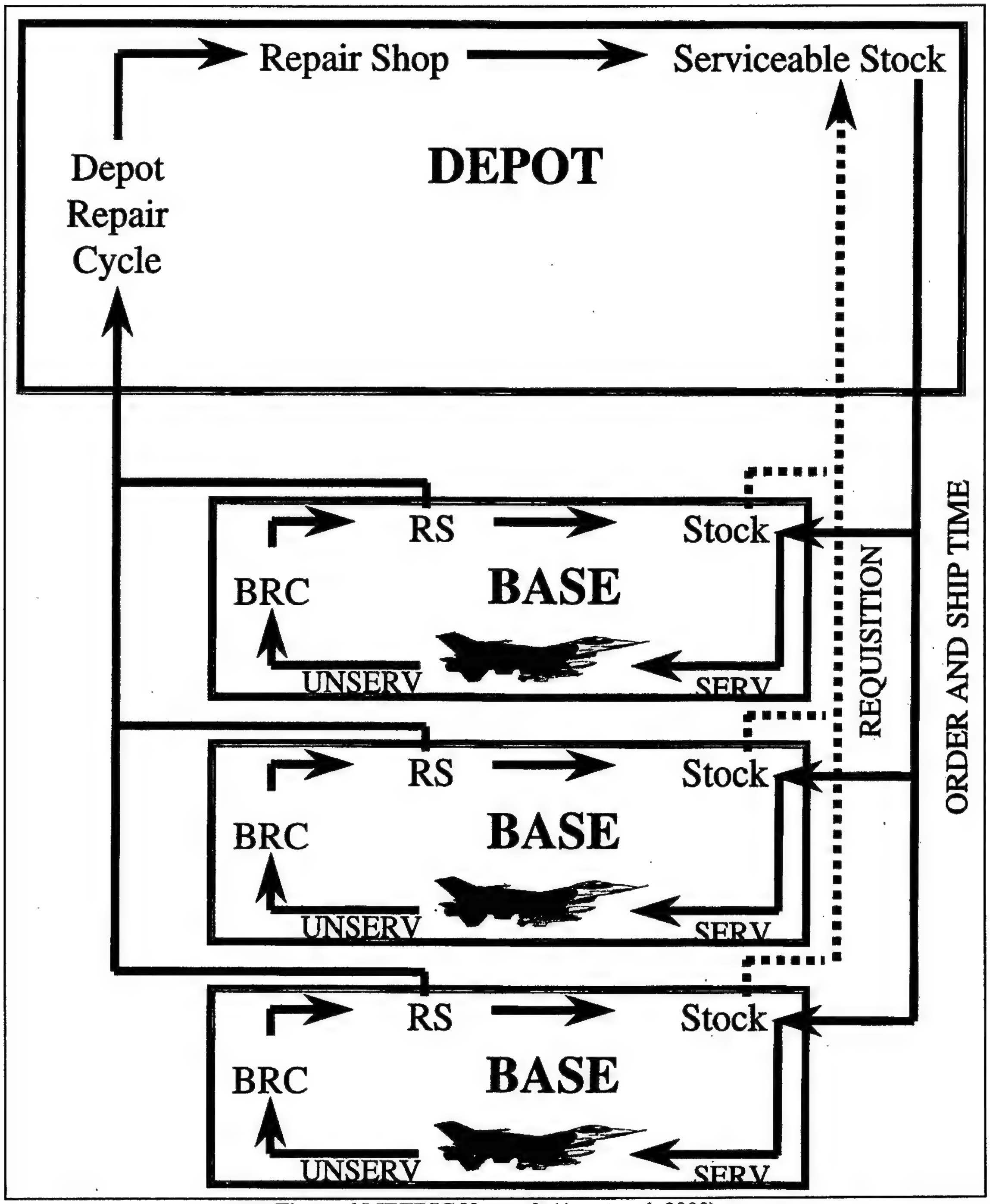

Figure 6 METRIC Network (Arostegui, 2000)

Mod-METRIC. In 1973, Muckstadt published an article in *Management Science* titled "A Model for a Multi-Item, Multi-Echelon, Multi-Indenture Inventory System." In it, Muckstadt expanded the METRIC model to accommodate the effects of SRU backorders

on the system. Again, the overall goal was to minimize expected backorders. The figure below shows the Mod-METRIC network for a single base.

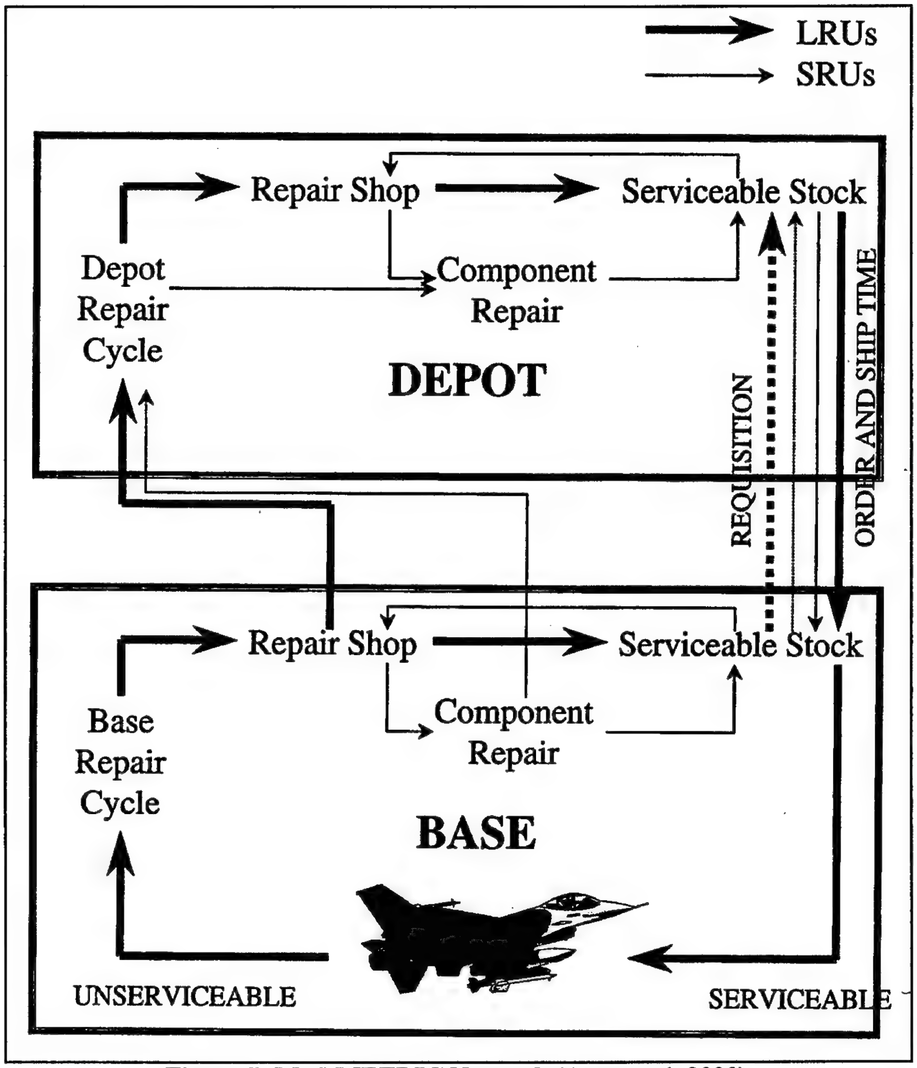

Figure 7: Mod-METRIC Network (Arostegui, 2000)

As shown in the diagram, Mod-METRIC adds a pipeline segment for base repair of SRUs and for the depot resupply of SRUs to the bases. In addition, base repair of an LRU may be delayed/impacted due to the lack of an SRU. One of the more important concepts behind Mod-METRIC is while the lack of a serviceable LRU grounds an aircraft, the lack of a serviceable SRU delays the LRU's repair.

Mod-METRIC was originally designed for the F-15's two F-100 engines. These engines are modular, with modules such as the inlet/fan module, the core engine, the fan drive turbine module, and the augmenter/exhaust nozzle module. When an engine fails, the engine is removed and replaced with a serviceable engine. The failed engine is then tested and the offending module is replaced. The module may be repaired at the base or the depot. In extreme cases, the entire engine is sent to the depot for repair. Despite being developed for this specific purpose, Mod-METRIC is generalizeable to many applications involving both LRUs and SRUs.

Mod-METRIC uses the basic METRIC assumptions and then adds several of its own. The model assumes that LRUs are expensive and directly degrade the mission when they fail, so the system should have a PBR close to 100%. In contrast, SRUs are relatively inexpensive and are remove and replace items. Some PBR for them is acceptable, but the system can more readily afford to have extra stock of the items and fill the depot repairable pipeline with them. Mod-METRIC assumes that every LRU failure is the result of just one SRU failure, with no "cascading failures" allowed. Finally, an SRU belongs to just one LRU (Arostegui, 2000).

In 1985, Graves published a paper that criticized the METRIC models for their use of the Poisson distribution for demands. He and others found that both METRIC and Mod-METRIC understated actual EBO values. Sherbrooke agreed, stating:

> "When the METRIC model was developed, it was clear that it understated base backorders. In most cases the error was not large, and the simplicity of METRIC seemed to overshadow its lack of precision (Sherbrooke, 1986: 311)."

Slay in 1980 developed the VARI-METRIC model, which resulted in a ten-fold improvement over METRIC results. Using the model, Graves found that METRIC differed by at least one unit in 11% of the cases he examined. VARI-METRIC differed in only 1% of the cases (Arostegui, 2000). Sherbrooke further refined Slay's algorithm in 1986 and published it in an article in *Operations Research* titled "VARI-METRIC: Improved Approximations for Multi-Indenture, Multi-Echelon Availability Models."

VARI-METRIC. The METRIC models are known as *first-order* models because they use simple averages to compute the number of units in the pipeline. VARI-METRIC is known as a *second-order* model because it uses both the mean and variance to compute the number of units in resupply. The network is the same as the Mod-METRIC model depicted in Figure 7.

VARI-METRIC is a stationary, stochastic demand model that deals with multi-echelon, multi-item, multi-location, multi-indenture systems. Its goal is to maximize system-wide aircraft availability. It assumes an (S-1, S) inventory policy at every echelon. As was the case with METRIC, repair capacity and parts are plentiful so repair time is independent of the number of units already in repair. It assumes a Poisson demand with a mean that is constant, but uses the negative binomial distribution for the base backorder process. No units are condemned, and no lateral resupply occurs between bases. The chart below shows the difference between the Poisson and negative binomial distributions. The negative binomial approximates the backorder distribution in a more realistic manner (Arostegui, 2000).

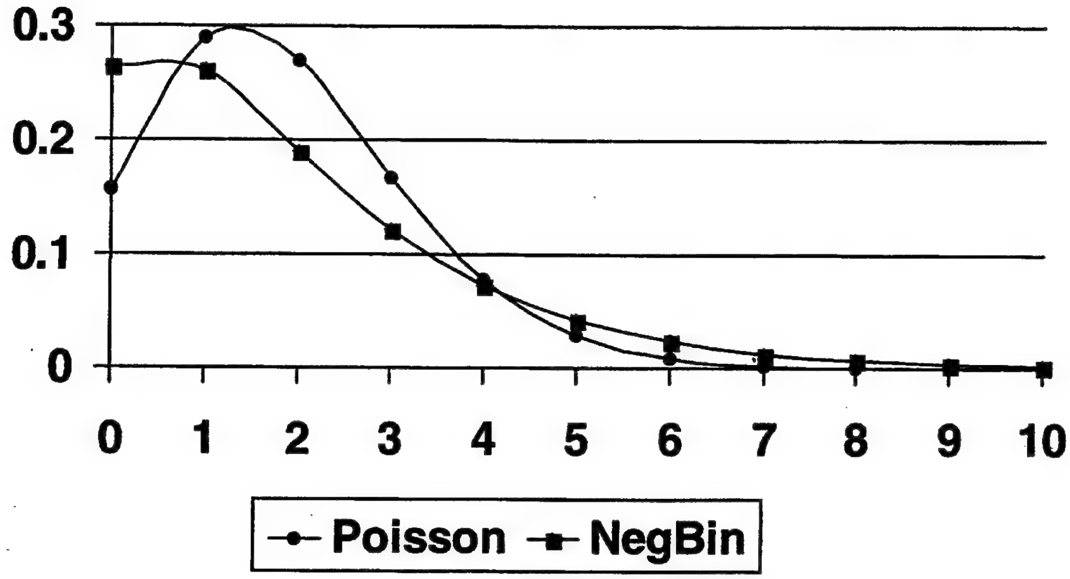

Figure 8: Negative Binomial vs. Poisson (Arostegui, 2000)

Dyna-METRIC. Peacetime flight operations provide a fairly stationary demand pattern for which to model inventory systems. The military environment, however, possesses several dynamic factors that necessitate the addition of dynamic processing capabilities. Wartime aircraft flying rates and support capabilities may fluctuate rapidly during a conflict. In addition, deploying aircraft usually leave some organic maintenance and resupply capabilities behind, and these take some time to "catch up" to the aircraft. Dyna-METRIC was developed to address these issues. The RAND organization developed a series of projects aimed at improving aircraft readiness and supportability, and these were used to develop and enhance the Dyna-METRIC model. Various releases of the model have been designed to support specific Air Force requirements. The first four releases were analytical models, while the last two are simulation-based. The analytical releases can assess the effect of different logistics scenarios, or compute spares

requirements to achieve specific availability goals. The simulation models can only provide assessments.

The Dyna-METRIC model is a stochastic, dynamic demand model that deals with multi-item, multi-location, multi-echelon, multi-indenture systems and attempts to maximize aircraft availability. The next section lists the assumptions the Dyna-METRIC model makes.

While similar to the METRIC models, Dyna-METRIC removes even more of the restrictive assumptions found in basic METRIC formulations. It assumes the LRU demands are proportional to either flying hours or sortie rate, and that demands arrive randomly based on some known mean and variance with either a Poisson or negative binomial distribution. In addition, repair and transportation times have known probability distributions, and there is unconstrained repair capability. Again, no lateral resupply takes place. All aircraft deployed to a single base are identical. In a major change to the previous METRIC models, cannibalization actions where holes in aircraft are consolidated are allowed. Dyna-METRIC assumes that "canns" occur instantly and that the ability to cann an LRU is either possible or not with no intermediate levels.

The simulation releases of Dyna-METRIC relax some of the assumptions further. Lateral resupply is allowed, and repair scheduling can take place on a priority basis. In addition, depot condemnation is allowed and battle damage of repair facilities can be modeled. However, because the model is a simulation, it cannot build a spares requirements list to achieve target goals (Arostegui, 2000).

Aircraft Sustainability Model (ASM). ASM was developed by LMI to provide a system-level approach in selecting spares mixes (Kline, et al, 1999: 1-2). ASM is a

stochastic, dynamic demand model that deals with multi-item, multi-location, multi-echelon, multi-indenture systems and attempts to maximize aircraft availability. It has the same assumptions as the Dyna-METRIC model. It also has the ability to both build an MRSP based on requirements and then evaluate that kit (or others) over a multi-day analysis period.

Kline, et al (1999) list seven factors in addition to aircraft availability and budget restraints. The first is item type. ASM was primarily developed to deal with high-cost, essential items, usually reparable in nature. It can, however, deal with consumable item that are generally lower-cost, throw-away items. Second, ASM deals with the indenture structure of the aircraft by examining both LRU and SRU pipelines and determining the impact of each. Third, common items, which are used on more than one type of aircraft, are also considered. This allows ASM to consider the impact of a ready pool of available assets for other aircraft. This does not have as large an impact on MRSP calculations, however, because MRSPs assume no resupply from outside the operating location. The fourth factor is cannibalization. As we will discuss later, ASM can model the consolidation of needed parts into the fewest aircraft possible in several ways.

The fifth factor ASM deals with is wartime vs. non-wartime conditions. Policies and flying hour requirements are vastly different during wartime than in peacetime. The sixth factor is the existence of starting stock where asset may already have been purchased. ASM incorporates these values into the shopping list for the optimal mix of spares. The final factor is a catchall that includes a number of item-specific factors such as demand rate, base and depot repair times, condemnation rates, and others (Kline, et al, 1999: 1-4). Together, they make up the flexible and powerful package that is ASM.

MRSP Characteristics and Components

The makeup of an MRSP is the result of a multitude of different factors. Policy decisions concerning flying rates and acceptable numbers of NMCS aircraft combine with known item factors to create an MRSP that is designed for a specific purpose. ASM uses these and other factors to compute an optimally sized kit that will support a unit for a specific cost at a specific availability level. This section will describe some of the most important factors and how ASM uses them to build an MRSP.

Range and Depth. The assets in an MRSP have a range and a depth designed to support the unit. The range is the number of unique assets in the kit, and the depth is the total number of each unique asset. For example, an MRSP may have 1000 unique items (the range) but have 1200 total items because it has more than one of some items. AFR 400-24 (War Reserve Policy) states that the composition of the MRSP is a product of the configuration, tasking, initial deployed maintenance capability, programmed arrival time of any planned follow-on maintenance units, and programmed supply support concepts for the specific MRSP (AFR 400-24: 24). When ASM uses these factors in the analysis, the range and depth are the result.

Maintenance Concept. As previously discussed, assets may be divided into LRUs and SRUs. LRUs can be further divided into remove/replace (RR) or remove/repair/replace (RRR) items. The maintenance concept at the operating location determines how ASM treats the two types of LRUs. In particular, the concept of a CIRF is designed to allow RRR items to be repaired closer to the operating location and also to centralize the repair facilities and thus reduce the total number of SRUs in the system. Planners designing kits

using ASM must consider exactly what the maintenance capabilities of the operating location will be and what impact that will have on the depth of parts in the MRSP.

Direct Support Objective. In the past, the direct support objective (DSO) was focused only on day 30 of the war. This was a result of a "consumable" outlook, which basically implied that having enough of an item on day 30 meant there was enough of the item on days prior to that (Mattern, 1993: 2-2). For reparable assets, however, this assumption may not be correct. A typical wartime scenario includes a "surge" period followed by a longer sustainment period, as shown in this example:

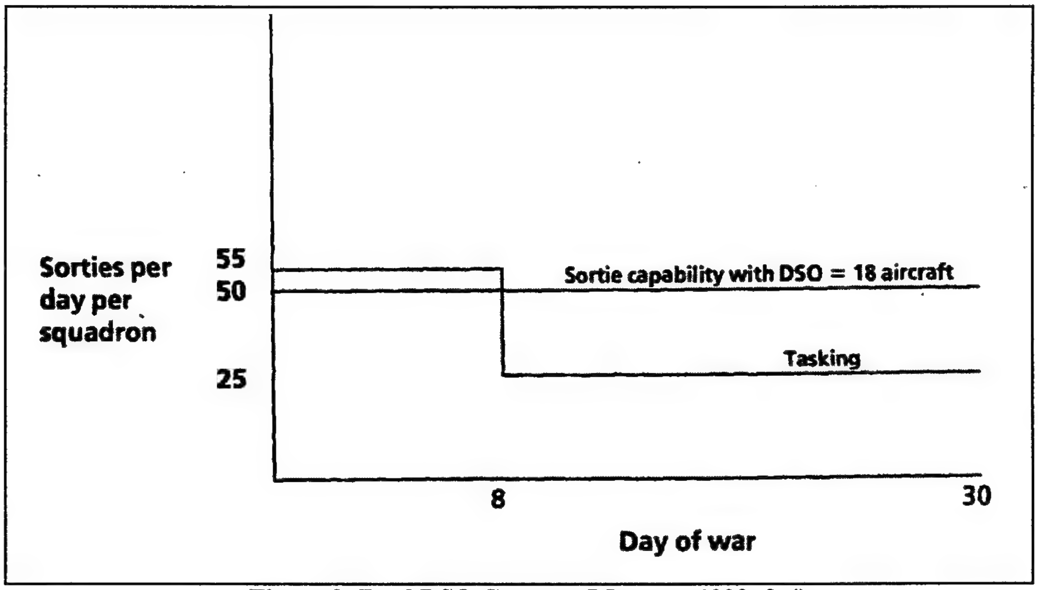

Figure 9: Dual DSO Concept (Mattern, 1993: 2-4)

As shown above, a DSO of 18 aircraft meets the requirement at day 30, but does not meet the requirement for the first eight days of the war. This prompted the Air Force to consider and adopt the concept of dual DSOs: one for the end of the surge period, and one for the sustainment period at the end of the war. ASM has the capability to use the dual DSO concept in its calculations.

The DSO directly affects the range and depth of spares in the MRSP. Reducing the DSO will reduce the number of spares purchased. This will also reduce the logistics footprint and airlift capacity needed to support the aircraft. The downside is that a when a DSO is reduced then the number of airframes available for mission planners is also reduced. Planners must determine the correct tradeoff that balances logistics footprint with mission success. DSOs vary by aircraft type and mission, and are defined in the War Mobilization Plan (WMP).

Flying Hour Requirements. The WMP also defines the flying hour requirements for the unit undergoing analysis. ASM uses the total flying hours per day during both the surge and sustainment periods to determine what assets will be necessary. The heavier the flying hour requirement, the more parts will be needed to maintain the desired DSO for the period.

Cannibalization. Cannibalization is a maintenance action taken when all other sources of parts have been exhausted. It involves removing items from one aircraft to place on another, and its effect is to consolidate "holes" in aircraft so more airframes are mission capable. Canning is an important consideration when running ASM because it is a real-world option and is used extensively during operations. Newer weapon systems such as the F-16 and F-15 have even been designed to make cannibalization easier (Arostegui, 2000). This section will discuss some assumptions about canning and look at an example.

ASM makes a number of assumptions with respect to cannibalization actions. First, it assumes that all cann actions take place at the operating base. No parts are canned from one aircraft at a base and then shipped to another base. Second, ASM

assumes items either may or may not be canned, with no regard to how easy or hard the cann action is. ASM has three options: cann all LRUs, cann LRUs according to their cann flag in the item properties, or do not cann any LRUs. ASM assumes that SRUs are always canned in the backshops when necessary (Kline, et al, 1999: 50).

Cannibalization has a large impact on the range and depth of assets in the MRSP. In essence, it provides yet another warehouse for assets at the operating location, so if cannibalization is allowed the number of parts required will be reduced. It also relaxes the somewhat cumbersome assumption that only one part is missing from each NMCS aircraft.

Item Characteristics. Every item ASM considers for inclusion in the MRSP has a set of factors that ASM uses to determine its optimal spares mix. Perhaps the most important factor is the daily demand rate of the item, which was discussed earlier in this chapter. Using the demand rate and repair cycle times, ASM can determine pipeline quantities. Depot variables such as the order and ship time (OST) and depot repair times are considered. Each item has a cannibalization flag (yes or no) and a quantity per aircraft (QPA) that tells ASM how many are needed and how many can be cannibalized if necessary. These and other factors are unique to each item and ASM takes each into account and balances them all to arrive at the solution. The final factor of interest to ASM is the item cost, which it uses to establish a shopping list which purchases items based on their contribution to aircraft availability (Kline, et al, 1999: 1-2). Planners use the list to purchase maximum aircraft availability for the allowable budget. For a more detailed examination of the item factors ASM uses, please see "Optimizing Spares Support: the Aircraft Sustainability Model," by Slay, et al (1999).

Centralized Inventory Management

A relatively new idea known as risk pooling advocates the centralization of inventory to reduce overhead and inventory investment costs. There are three critical points to consider in a risk pooling scenario:

1. Centralizing inventory reduces safety stock and average inventory. This point implies that if demand is high in one area of the market, then it usually is lower in another, so a centralized warehouse can reallocate assets faster than a non-centralized one. The military follows this concept to some extent, canceling lower-priority missions to sustain high operations tempo in other areas.
2. The second point deals with the coefficient of variation, which is the standard deviation divided by the average demand (Simchi-Levi, et al, 2000: 57). The higher this coefficient is, the greater the benefit of risk pooling will be. This is due to the fact that safety stock calculations are almost always based on the standard deviation. The greater the reduction in safety stock, the greater the overall benefit will be.
3. The final point is that the benefits of risk pooling depend on how highly correlated the demand in the markets are (Simchi-Levi, et al, 2000: 60). If the demands are highly correlated, then they will rise and fall together, and no offset of demand by reallocating assets will be possible. In a military setting, this would be equivalent to fighting a major theater war in both Asia and the Middle East at the same time. The reality for the near future is more likely that of small-scale contingencies in a few locations or a single major deployment covered by an AEF.

Bases currently stock MRSPs built for scenarios defined in the WMP, which are then adjusted before deployment for the actual scenario expected. Each base stocks and maintains their own kits. The risk pooling theory states that a centralized management facility with some portion of the total would result in reduced overhead and inventory investment while still maintaining the same level of support. The Navy recently used centralized management to accomplish this result.

A Navy Example

The Navy faces some of the same types of logistics footprint problems the Air Force does. They also face two additional problems: their ships have less warehouse space than the typical deployed location, and logistics response times are greater because the parts' destination is constantly moving. To improve the support for the Tomahawk Land Attack Missile (TLAM) Afloat Planning System (APS), the Navy turned to contractor logistics support. The Defense Logistics Agency and Federal Express (FEDEX) developed a logistics support system that significantly reduced costs while providing better support. The relevance to this thesis is that the improvement was accomplished through centralized inventory management and high-speed transit.

The USS Carl Vinson was the test ship for the new system. Typically, the ship deployed with a range of 237 and a depth of 535 parts for the APS. This kit of spares was valued in excess of $1 million. Under the new system, the Carl Vinson deployed with 40 parts having a value of $195,818. All other parts are stored at a Government-Owned/Contractor Operated facility in Memphis, TN. The average transit time for parts requested via the internet from the central facility to the ship was 6 1/2 days; far better

than the published Navy time frame of 32 days. When the report we reviewed was published, nine afloat users and six ashore customers using the system had reported a total cost avoidance of $12,680,000. FEDEX maintains a 99% inventory accuracy rate and boasts an impressive 99% on-time delivery rate as well. Through this centralization of assets, the Navy has improved response time, reduced inventory, and increased afloat storage space (Navy Acquisition Reform Website, 2000).

III. Chapter 3—Methodology

Overview

This chapter discusses the tools and techniques used to answer the central thesis question. It begins with a summary statement of the problem and then examines the data sets used to accomplish the analysis. It finishes with a discussion of the assumptions made, the scenarios used, and the use of the ASM model for the thesis question.

Problem Summary

The purpose of this research is to determine if centralized management of MRSP assets would result in an overall savings without sacrificing availability levels in the process. To simulate this, imagine two different deployments. In the first, two squadrons

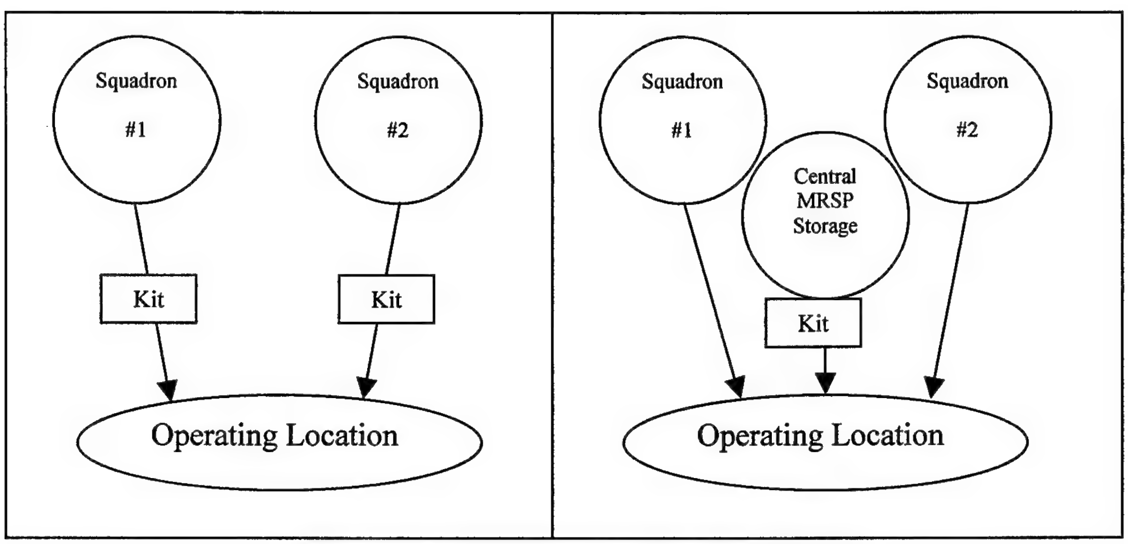

Figure 10: Traditional vs. Proposed Management

of aircraft deploy with their own individual MRSP to the same location and commence operations. There are two kits brought from different bases but having the same amount

of parts in each. In the second scenario, the two squadrons deploy to the same base, but their kit comes from a central location and is built to sustain both squadrons' aircraft at the same time. The figure above illustrates this. At first, it appears the added storage facility will increase costs, but it is important to remember that each base has a War Readiness Element staffed by supply personnel to manage the kits. Often, part-time personnel augment these elements, which reduces manpower in there primary sections as well. Additionally, this thesis will attempt to show that the inventory reductions gained by centralizing the kits are substantial and justify the setup costs of the central facilities.

Data

This research is focused at reducing the logistics footprint of deployed aircraft. As such, three different weapon system types were chosen to represent their roles: fighter, airlifter, and bomber. The F-15C, C-17A, and B-52H, respectively, were selected based on their typical wartime roles. MRSP data from the D087 database (used to build up all MRSPs) was obtained from HQ AFMC/XP. For the F-15C, kit data file 0D240AA was used. Kit file 1L2300A was used for the C-17A analysis. B-52H data came from the kit data file 1C060BA. The kit files are text files with both peacetime and wartime data for all items that might be assigned to an MRSP. They also include pre-specified buy quantities for items the Air Force has deemed essential to the MRSP. This quantity is flagged as the negotiated level quantity in ASM. Negotiated levels are set for some non-optimized (NOP) items, which are items that are required by the Air Force but not used in the optimization calculations. In addition, a generic run scenario is included with typical

settings for an MRSP calculation run. No changes were made to the raw data in the kit files.

The actual range and depth for each MRSP was determined by ASM. The files include items which have pre-specified quantities in the negotiated level field. Table 2 shows the total number of items for which data is included, the range and depth of the items with negotiated levels, and the total cost of these parts. This total cost represents a floor below which ASM will not buy.

Table 2: Negotiated Levels

Aircraft	Total Items	Neg Lv Range	Neg Lv Depth	Total Neg Lv Cost
F-15C	467	121	179	$6,960,610.92
C-17A	233	13	443	$7,461,129.71
B-52H	249	16	144	$10,240,071.85

The F-15C kit has the most number of items for consideration, but the total negotiated level cost is lowest. The C-17A, the newest aircraft in the study, has the fewest total items but the depth of negotiated items is the greatest. The B-52H has the highest negotiated level cost of the three aircraft but the lowest negotiated level depth.

Aircraft Sustainability Model

The ASM program was installed on an Intel Celeron 400Mhz personal computer running Microsoft's Windows Millennium Edition. Version 6.21 of the software was used. ASM's interface is user-friendly and uses a database structure to manage the various runs. Radio buttons allow options to be turned on and off, and numerical data is entered in clearly labeled fields. Kit data is imported from the D087 raw file using the Kit→Import Kit Data→Import USAF D087 Data command. The proper kit is chosen

and ASM imports the data, converting it to ASM's file structure. An option to change baseline kit parameters such as the number of aircraft and the flying profile is offered, but was not used in this research. Changes to the flying profile and number of aircraft were made to each scenario run rather than to the baseline kit file. This allowed the file to be used for every run to maintain continuity of data. Once the baseline kit is created, the user can move on to creating scenarios and running requirements computations.

Global Settings. Many options in ASM were set and then remained static throughout the runs for all aircraft. On the "Parameters" page, the Asset Projection field was changed to current and the Coverage Period was zero. Figure 11 shows the "Advanced Parameters" page, which was not changed once it was set:

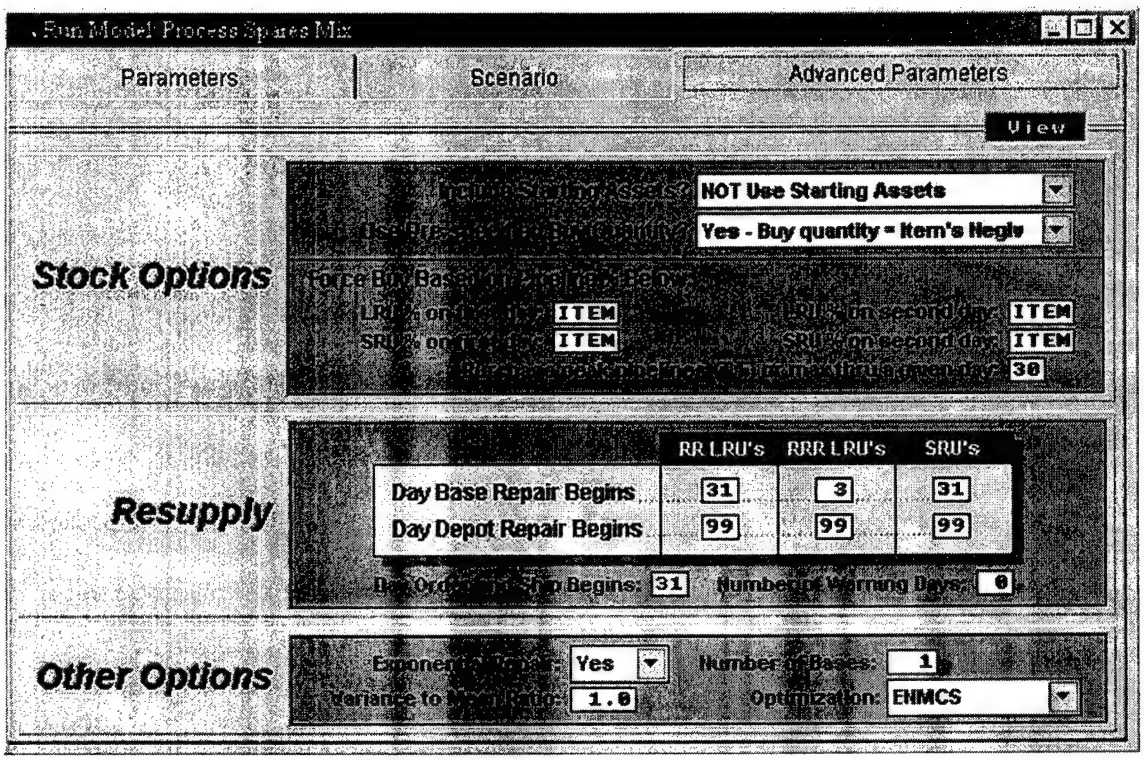

Figure 11: Advanced Parameters

The starting assets field tells ASM to create a new kit without considering items that are already in Air Force inventory. The Pre-specified buy quantity field forces ASM to use

the negotiated levels discussed earlier. The Resupply fields force ASM to support the aircraft without depot repair and resupply, which is the whole purpose of the MRSP concept. In Other Options, exponential repair is more realistic and there is only one base to support. The Variance to Mean Ratio was kept at 1.0 and the model was asked to optimize the scenarios based on the expected number of aircraft NMCS at a certain day or days.

Changing Variables. ASM has the option to run requirements for MRSPs based on the input variables, or run evaluations on a pre-built MRSP supporting different scenarios. We are examining the size and cost of kits for different scenarios, so the model was used to run requirements computations and build new kits. This section describes what variables were changed and why.

ASM uses total flying hours as the primary driver of demands for items (Kline, et al, 1999: 2-13). The Scenario page allows the user to set the total flying hours for days 1-60 individually. This allows the establishment of surge and sustainment periods, or any other scenario the user wishes to evaluate. Figure 12 shows a sample scenario page (values shown are default values and were not used in the actual research). The Non-Wartime and Wartime fields are used when evaluating a pre-built MRSP and do not affect requirements computations. This was verified by making numerous requirements runs with different sortie rates and hours with no effect on the computed kit size. Wartime demands were not decelerated for any aircraft. The flying hour profile for the desired scenario is typed into the appropriate fields in the Wartime Flying Hours section. The final step was naming the run number for future reference and then running the requirements computation in ASM.

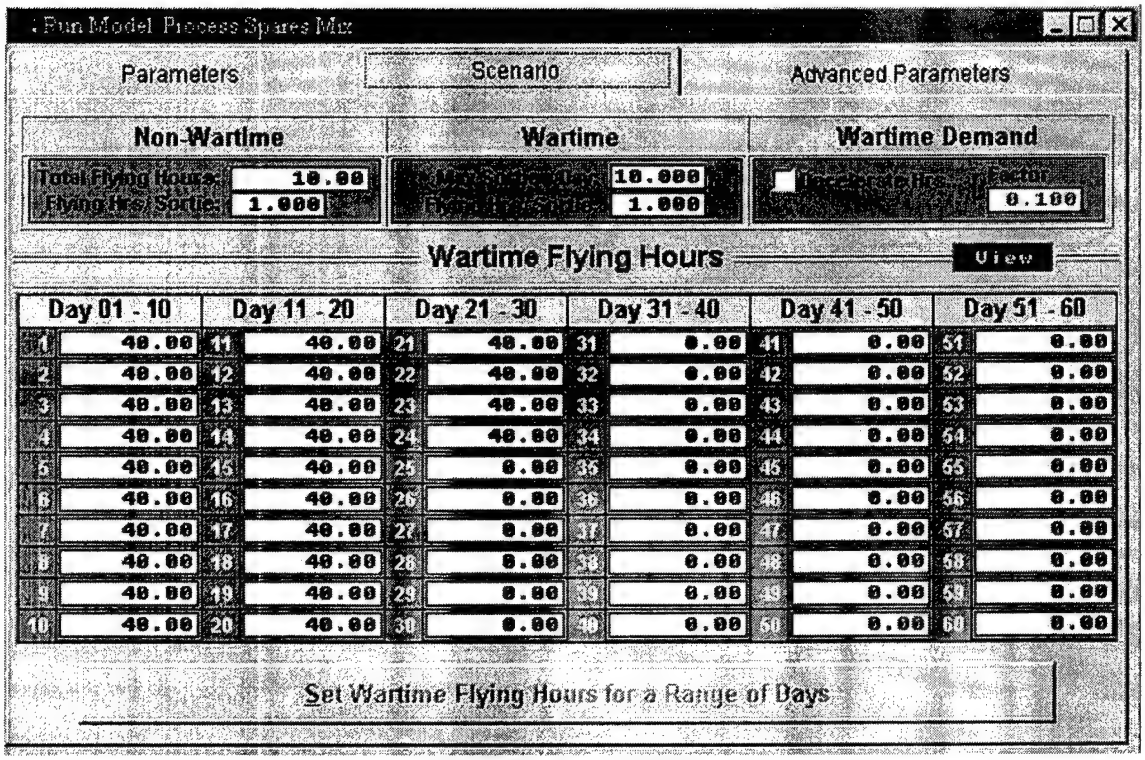

Figure 12: Scenarios Page

One Base/Two Squadrons

The first theoretical deployment considered was that of two squadrons deploying to the same location. In this case, baseline kits supporting 24 F-15C, 12 C-17A, and 12 B-52H aircraft were imported. The wartime flying hours were adjusted to create eight different scenarios with a difference of 10 hours flying time between scenarios. The requirements run shopping lists were then exported in Microsoft Excel format and analyzed. The baseline kits were multiplied by two to simulate the arrival of two squadrons from different bases. This is based on the assumption that demand rates for the aircraft from different bases are the same.

To simulate a customized MRSP arriving from a centralized management facility, an MRSP was created to support 48 F-15C, 24 C-17A, and 24 B-52H aircraft. The flying

hours were doubled for each of the eight scenarios and then requirement runs were created. The shopping lists were again exported to Excel and the differences between the two runs were examined.

One important aspect of this scenario involves the impact of cannibalization on the reduction in parts. The scenarios were run with full cannibalization, but in the first case where each squadron brings its own kit the cannibalization occurs only within that squadron. Conversations with maintenance officers indicate that squadrons would allow cannibalization between squadrons if necessary. In the second case in which a kit for the total number of deployed aircraft is created, ASM assumes full cannibalization for the entire number of aircraft. The overall DSO remains the same, but there may be some change. To investigate, another series of runs identical to the first was made with the cannibalization flag switched to "none."

Centralized Intermediate Repair Facility (CIRF)

The second theoretical deployment involves the establishment of a CIRF supporting several smaller detachments of aircraft in a forward operating location (FOL). ASM version 6.21 has a preliminary CIRF analysis capability called the USAF FSL function. It must be activated by editing the model.ini file and changing the UserType field to UserType=USAFFSL. Once the model is restarted, the FSL option becomes available. ASM uses the term Forward Support Location (FSL) for the CIRF, and FOL for the bases in the FOL the aircraft are deployed to. This terminology will be used for the remainder of the discussion.

The FSL option is undocumented so the AFLMA provided information on its use. It allows the assignment of pre-built MRSPs to FOLs and then calculates the parts required if some were stored at the FSL and some stored at the FOLs. The options available in the FSL page are shown in Figure 13

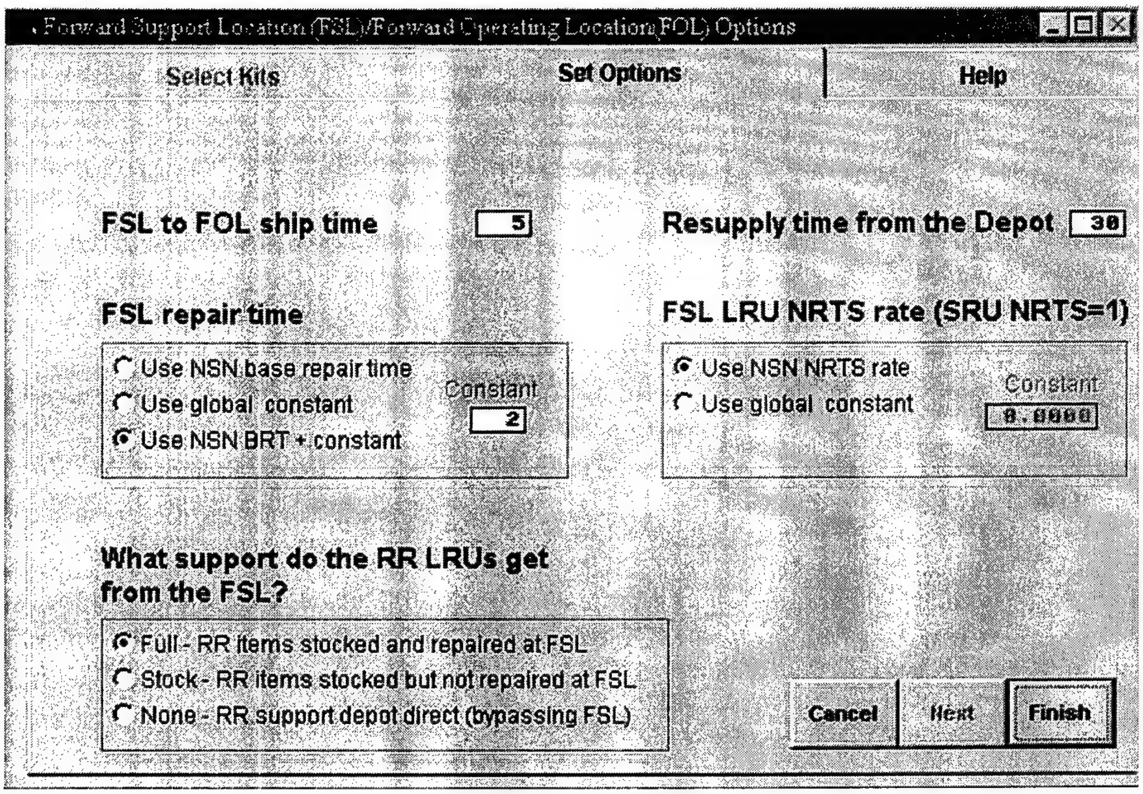

Figure 13: FSL Options

The FSL to FOL ship time is the time it takes an item to travel from the FSL to the FOL, and ASM assumes this is equal for all FOLs. The default value of five days was used for all runs. Five days seemed to be a reasonable time frame and there was no conflicting documentation to suggest otherwise. The resupply time from the depot was also kept at the default 30 days. The FSL repair time assumes that some reduction in base repair capability occurs, so the FSL repairs items based on the items' base repair time (BRT) plus a constant. Again, the default value of two days was used. The LRU not-reparable

this station (NRTS) rate is assumed to be the same as the items base NRTS rate, but the SRU rate is set to 100% because the FSL does not have the same repair capabilities as a depot. Finally, the RR LRU support was set to Stock – RR items stocked but not repaired at FSL.

The first page of the FSL option is the kit selection screen. Kits are deselected by filling in a small rectangle next to their name. Any unselected kits will be considered in the analysis. The FSL option assumes that each FOL receives a kit, so if four kits are assigned, then four FOLs will be assumed. For this situation we assumed the demands and flying schedules at each FOL were identical, so one baseline MRSP was created and then copied to produce the desired number of FOLs. After the run is made, ASM generates an Excel output file in the IAF_Port folder of the ASM directory. This file has four columns—NSN, fsl_target, folsumtarg, and tot_target. The fsl_target is the number of each NSN assigned to the FSL. The folsumtarg is the total number of items assigned to all the FOLs, and should be divided by the number of FOLs to determine how many parts go to each FOL. The tot_target column is the total number of parts to be purchased.

The FSL output file NSNs are identical to the individual kit files, so when both are sorted by NSN it was a simple task to import the item cost and LRU/SRU flag. A template Excel file with the item data and LRU/SRU flags was created and the FSL option data was imported. Calculations for the FSL total cost and number of LRUs and SRUs were made. As in the first deployment considered, eight flying hour profiles were created. The FSL option scenarios were be compared to a deployment in which each squadron takes an individual MRSP with no intermediate repair facility. In this case, cannibalization was not an issue because the FOLs are separated geographically.

Once the scenarios were defined and ASM's parameters set to run requirements computations for MRSP assets, the shopping lists and FSL totals were exported to Excel. The data was manipulated to find total cost and reductions in total assets. The next chapter describes the data analysis in detail.

IV. Chapter 4—Analysis

Overview

This chapter reports the results of using ASM to determine the effect of a theoretical centralized MRSP storage facility. The chapter is organized by aircraft type—F-15C, C-17A, and B-52H. Each section begins with a discussion of the flying hour scenarios for each aircraft and why they were chosen. The next section shows the unique ASM parameters that changed for each aircraft according to Air Force doctrine or mission specialty. Next, summarized ASM results for total cost, the range and depth of parts, and a breakdown of LRUs/SRUs are shown, as well as differences between the traditional deployment and the proposed centralized concepts. Finally, the same scenario results are shown with cannibalization turned off to show the effects canning has on the amount of assets in the MRSPs.

There are two items of interest shown in the results tables. The first is total MRSP cost, which is reported by ASM and easily computed from the buy totals ASM outputs for each run. Cost is important because the military has insufficient funds to purchase all the assets it needs. Therefore, any cost savings resulting from the centralized MRSP concept are significant. The second item of interest is the range and depth of parts in the computed MRSPs, which directly affect the logistics footprint of the deployed squadrons. The percentages of LRUs and SRUs are reported as well, which may provide some insight into the makeup of the kits.

F-15C

<u>Flying Hour Profile Scenarios.</u> The fighter aircraft representative has the highest number of assets under review for inclusion in the MRSP. Recall that the F-15C MRSP data contains both LRUs and SRUs, and some LRUs are RR or RRR. The flying hour profile for the aircraft was derived from the default values found in the D087 file. Fighter aircraft such as the F-15C face a surge period early in the deployment, and then a longer sustainment phase with fewer flying hours per day. For the F-15C, the surge period lasts 5 days and the sustainment period lasts until a pipeline is established at day 30. Table 3 shows the eight scenarios used during the research for a 24-aircraft squadron.

Table 3: Flying Hour Profile for 24 F-15C

Day	Scen. 1	Scen. 2	Scen. 3	Scen. 4	Scen. 5	Scen. 6	Scen. 7	Scen. 8
1-5	52	62	72	82	92	102	112	122
6-30	25	35	45	55	65	75	85	95

A single F-15C flying in scenario 1 would fly 2.17 hours per day, while scenario 8 would result in each aircraft flying 5 hours or per day during the surge period. The values for scenario 4 are the D087 default values.

For the 48-aircraft scenarios, the flying hour profile values were doubled. Table 4 shows the eight scenarios used for 48 aircraft:

Table 4: Flying Hour Profile for 48 F-15C

Day	Scen. 1	Scen. 2	Scen. 3	Scen. 4	Scen. 5	Scen. 6	Scen. 7	Scen. 8
1-5	104	124	144	164	184	204	224	244
6-30	50	70	90	110	130	150	170	190

The flying hour profiles result in the same sortie rates and hours as the 24-aircraft scenarios. The scenarios place the same demands on the aircraft, and thus the parts in the MRSPs, as two squadrons deploying with their own kits. The next section describes the ASM parameters unique to runs involving the F-15C.

ASM Parameters. The basic parameters page in ASM includes the Fleet Size, 1st Analysis Day, and 2nd Analysis day fields. For the first set of runs, the Fleet Size was set to 24 aircraft. The 1st Analysis day tells ASM what DSO the MRSP should support at the end of the surge period, and the 2nd Analysis day does the same at the end of the support period. For the F-15C, the default values from D087 were used. The 1st Analysis day is day 5 and the DSO is 71.66%, or 17.2 available aircraft at the end of day 5. The 2nd Analysis day is day 30 with a DSO of 63.33%, or 15.2 aircraft available at the end of day 30. For the second set of runs with 48 aircraft, the DSO percentages remained the same, which changed the 1st Analysis availability goal to 34.4 aircraft and the 2nd Analysis day goal to 30.4. Cannibalization was set to "Full" for this set of runs.

Results with Cannibalization. The first data set to report is the case of two 24-aircraft squadrons deploying with their own MRSPs.

Table 5: Two 24 F-15C MRSPs

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
Total Cost	$16,621,552.16	$18,430,770.58	$21,063,598.44	$23,084,285.82	$25,713,813.70	$29,454,300.14	$33,024,477.90	$38,264,945.20
Range	142	154	167	176	189	208	218	237
Depth	556	658	780	906	1066	1234	1438	1650
% LRUs	81.29%	84.19%	86.67%	88.08%	87.80%	87.68%	87.48%	87.15%
% SRUs	18.71%	15.81%	13.33%	11.92%	12.20%	12.32%	12.52%	12.85%
% RR	76.62%	80.24%	83.33%	85.21%	85.37%	85.58%	85.54%	85.33%
% RRR	23.38%	19.76%	16.67%	14.79%	14.63%	14.42%	14.46%	14.67%

The next table shows the results of a custom MRSP designed to support all 48 aircraft:

Table 6: One 48 F-15C MRSP

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
Total Cost	$10,954,161.19	$13,002,477.03	$15,577,981.39	$17,729,979.29	$20,542,407.13	$22,909,961.25	$26,075,228.17	$29,395,736.62
Range	170	185	198	212	223	232	247	255
Depth	430	543	672	802	947	1090	1248	1418
% LRUs	87.91%	90.42%	92.26%	93.52%	93.77%	93.94%	93.51%	92.74%
% SRUs	12.09%	9.58%	7.74%	6.48%	6.23%	6.06%	6.49%	7.26%
% RR	84.88%	88.03%	90.33%	91.90%	92.40%	92.75%	92.47%	91.82%
% RRR	15.12%	11.97%	9.67%	8.10%	7.60%	7.25%	7.53%	8.18%

Note again that the only item changed between the two sets of runs (for 24 and 48 aircraft) is the number of aircraft assigned to the base. The flying hours were doubled, so

each aircraft flies the same profile in each scenario. Table 7 shows the differences in total cost and total assets in the kits.

Table 7: F-15C Scenario Differences

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
Total Cost	$5,667,390.97	$5,428,293.55	$5,485,617.05	$5,354,306.53	$5,171,406.57	$6,544,338.89	$6,949,249.73	$8,869,208.58
Total Parts	126	115	108	104	119	144	190	232

The difference in total cost decreases from scenarios 1 to 5, but then quickly increases to $8.8 million by scenario 8. Likewise, the number of parts in the kit decreases to scenario 5 and then nearly doubles by scenario 8. The customized MRSP from the centralized storage area is cheaper and smaller than two kits from different bases in every scenario. To test the effects of cannibalization on the reduction in assets, the scenarios were run again with cannibalization turned off.

Results without Cannibalization. Tables 8 and 9 show the results after the cannibalization flag was switched to "none:"

Table 8: Two 24 F-15C MRSPs without Cannibalization

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
Total Cost	$36,719,614.08	$44,703,751.20	$51,611,771.86	$57,976,595.82	$64,994,490.66	$71,985,193.90	$78,273,351.12	$84,570,415.02
Range	384	389	393	394	395	396	396	396
Depth	1904	2300	2614	2960	3288	3566	3880	4182
% LRUs	85.08%	85.91%	86.46%	87.16%	87.90%	88.50%	88.25%	88.57%
% SRUs	14.92%	14.09%	13.54%	12.84%	12.10%	11.50%	11.75%	11.43%
% RR	82.67%	83.39%	84.01%	84.80%	85.40%	85.98%	85.82%	86.18%
% RRR	17.33%	16.61%	15.99%	15.20%	14.60%	14.02%	14.18%	13.82%

Table 9: One 48 F-15C MRSP without Cannibalization

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
Total Cost	$24,179,229.87	$30,303,388.87	$36,423,489.40	$42,279,930.59	$48,145,633.95	$54,040,210.22	$59,966,720.05	$65,576,753.82
Range	388	391	393	396	396	396	396	396
Depth	1327	1655	1946	2228	2495	2765	3023	3281
% LRUs	87.04%	87.61%	88.28%	88.87%	89.30%	89.58%	89.91%	90.06%
% SRUs	12.96%	12.39%	11.72%	11.13%	10.70%	10.42%	10.09%	9.94%
% RR	84.85%	85.56%	86.18%	86.76%	87.09%	87.41%	87.66%	87.90%
% RRR	15.15%	14.44%	13.82%	13.24%	12.91%	12.59%	12.34%	12.10%

The differences between the two kits are shown in Table 10.

Table 10: F-15C Differences without Cannibalization

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
Total Cost	$12,540,384.21	$14,400,362.33	$15,188,282.46	$15,696,665.23	$16,848,856.71	$17,944,983.68	$18,306,631.07	$18,993,661.20
Total Parts	577	645	668	732	793	801	857	901

In this case, there is still a sizeable savings gained with the development of a customized MRSP. While much larger than the standard MRSPs, the centralized management MRSPs still show a reduction in cost and footprint.

F-15C CIRF Analysis

Flying Hour Profiles. Chapter three discussed the application of ASM's FSL option to the F-15C. This section reports the results of that analysis. The CIRF option was designed for a scenario in which several small groups of aircraft are deployed throughout a region of conflict. 24-aircraft groups were judged to be too large for a reasonable analysis. A scenario with four 12-aircraft groups was designed. The total number of deployed aircraft remains at 48. The flying hour profiles were originally reduced by half from the 24-aircraft profiles, but this was judged to be too low for surge operations. The final flying hour profiles are shown in Table 11:

Table 11: 12 F-15C CIRF Flying Hour Profiles

Day	Scen. 1	Scen. 2	Scen. 3	Scen. 4	Scen. 5	Scen. 6	Scen. 7	Scen. 8
1-5	31	41	51	61	71	81	91	101
6-30	17.5	27.5	37.5	47.5	57.5	67.5	77.5	87.5

Scenario 1 involves a single aircraft flying 2.6 hours per day, and scenario 8 brings that up to two 8.4 hours per day. The DSO at day five remained at 71.66%. The CIRF section of chapter three discusses the other parameters.

Results with Cannibalization. The first set of data is the kit cost, depth, and range of four individual MRSPs deployed with four 12-aircraft squadrons with no CIRF established. Table 12 shows the results.

Table 12: Four 12 F-15C MRSPs with No CIRF

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
Total Cost	$38,423,127.36	$49,337,072.88	$61,574,682.16	$78,766,945.88	$98,716,792.04	$117,668,401.72	$135,124,065.80	$154,640,818.40
Range	151	205	234	271	297	317	323	329
Depth	1292	1664	2056	2528	2960	3400	3812	4168

The next table shows the results of the establishment of a CIRF supporting the four FOLs with 12 F-15C aircraft at each location.

Table 13: 48 F-15C with CIRF Results Summary

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
Total Cost	$6,008,128.37	$13,434,730.61	$22,692,881.27	$34,584,379.13	$47,299,079.13	$59,761,802.43	$70,221,877.35	$81,995,891.91
Total Parts	240	532	805	1178	1470	1733	2023	2189

Table 14: CIRF vs. Four 12 F-15C Kits

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
Total Cost	$32,414,998.99	$35,902,342.27	$38,881,800.89	$44,182,566.75	$51,417,712.91	$57,906,599.29	$64,902,188.45	$72,644,926.49
FSL Range	47	47	48	48	48	48	48	49
FSL Depth	52	52	55	54	58	59	65	71
FOL Range	92	101	118	127	142	161	171	189
FOL Depth	1000	1080	1196	1296	1432	1608	1724	1908
Total Range	139	148	165	174	189	208	218	236
Total Depth	1052	1132	1251	1350	1490	1667	1789	1979

The savings resulting from the CIRF concept quickly rise as the flying hours increase. By scenario 6, two CIRFs supporting 96 aircraft could be established for the cost of four 12-aircraft kits.

Table 15 shows the breakdown of assets by LRU and SRU for each concept.

Table 15: F-15C LRU/SRU Totals

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
FSL LRUs	1000	1080	1199	1298	1438	1615	1737	1927
FSL SRUs	52	52	52	52	52	52	52	52
FSL Total	1052	1132	1251	1350	1490	1667	1789	1979
4 Kit LRUs	1040	1280	1580	1964	2332	2760	3108	3440
4 Kit SRUs	252	384	476	564	628	640	704	728
4 Kit Total	1292	1664	2056	2528	2960	3400	3812	4168

It shows that ASM assigns only 52 SRUs to the CIRF no matter what the flying hour profile is, while the four kit totals steadily increase the number of SRUs. This is most likely due to the way ASM deals with CIRF implementation. The FSL cannot repair

SRUs, but it can and does repair a significant number of LRUs, and provides a risk pooling effect that reduces the total number of stocked items.

C-17A

Flying Hour Profile Scenarios. The C-17A is the representative cargo aircraft. While its role as a tactical airlifter holds some merit, the decision was made to model deployed C-17s acting in a strategic, long-range cargo role. This was the default D-87 scenario as well. The C-17 is expected to deploy supplies during the first days of the war, sustain deployed forces, and then redeploy forces home after hostilities end. There is usually too little airlift capacity, so the C-17 is tasked for as many hours as possible with no surge or sustainment period. The flying hour profile reflects this, as it is a constant number of hours from days 1 to 45. Table 16 shows the scenarios used for 12 deployed C-17s.

Table 16: Flying Hour Profile for 12 C-17A

Day	Scen. 1	Scen. 2	Scen. 3	Scen. 4	Scen. 5	Scen. 6	Scen. 7	Scen. 8
1-45	145	155	165	175	185	195	205	215

Table 17 shows the scenarios used for 24 deployed C-17s.

Table 17: Flying Hour Profile for 24 C-17A

Day	Scen. 1	Scen. 2	Scen. 3	Scen. 4	Scen. 5	Scen. 6	Scen. 7	Scen. 8
1-45	290	310	330	350	370	390	410	430

Again, the flying hours were doubled for the proposed centralized management concept. Scenario 1 results in a single aircraft flying 12.1 hours per day, and scenario 8 results in the aircraft flying 17.9 hours per day.

ASM Parameters. For the first set of runs, the Fleet Size was set to 12 aircraft. For the C-17A, the default values from D087 were used for the 1st Analysis day. No second

analysis day is needed because the kit is designed to support the aircraft through day 45 of the war. The 1st Analysis day is day 45 and the DSO is 93.08%, or 11.17 available aircraft at the end of day 45. For the second set of runs with 24 aircraft, the DSO percentage remained the same, which changed the 1st Analysis availability goal to 22.34 aircraft. Cannibalization was set to "Full" for this set of runs.

<u>Results with Cannibalization.</u> The first data set to report is the case of two 12-aircraft squadrons deploying with their own MRSPs.

Table 18: Two 12 C-17A MRSPs

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
Total Cost	$190,856,354.62	$200,076,460.78	$209,532,417.50	$218,237,954.78	$226,719,260.36	$235,968,589.74	$243,965,689.66	$252,902,571.66
Range	233	233	233	233	233	233	233	233
Depth	3250	3372	3464	3554	3640	3746	3856	3940
% LRUs	100%	100%	100%	100%	100%	100%	100%	100%
% SRUs	0%	0%	0%	0%	0%	0%	0%	0%
% RR	100%	100%	100%	100%	100%	100%	100%	100%
% RRR	0%	0%	0%	0%	0%	0%	0%	0%

The next table shows the results of a custom MRSP designed to support all 48 aircraft:

Table 19: One 24 C-17A MRSP

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
Total Cost	$133,909,399.73	$141,895,202.35	$149,959,787.04	$157,579,551.48	$165,764,819.03	$173,406,904.20	$180,943,879.26	$189,050,774.61
Range	233	233	233	233	233	233	233	233
Depth	2047	2127	2213	2302	2375	2454	2551	2631
% LRUs	100%	100%	100%	100%	100%	100%	100%	100%
% SRUs	0%	0%	0%	0%	0%	0%	0%	0%
% RR	100%	100%	100%	100%	100%	100%	100%	100%
% RRR	0%	0%	0%	0%	0%	0%	0%	0%

Note again that the only item changed between the two sets of runs (for 12 and 24 aircraft) is the number of aircraft assigned to the base. The flying hours were doubled, so each aircraft flies the same profile in each scenario. Table 20 shows the differences in total cost and total assets in the kits.

Table 20: C-17A Scenario Differences

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
Total Cost	$56,946,954.89	$58,181,258.43	$59,572,630.46	$60,658,403.30	$60,954,441.33	$62,561,685.54	$63,021,810.40	$63,851,797.05
Total Parts	1203	1245	1251	1252	1265	1292	1305	1309

The difference in total cost increases steadily with the flying hours. The number of assets in the kits also increases with flying hours. Note that because all the assets in the C-17A

kit are LRUs the cost savings is quite substantial when compared to the F-15C scenarios. The customized MRSP from the centralized storage area is cheaper and smaller than two kits from different bases in every scenario. To test the effects of cannibalization on the reduction in assets, the scenarios were run again with cannibalization turned off.

Results without Cannibalization. Tables 21 and 22 show the results after the cannibalization flag was switched to "none:"

Table 21: Two 12 C-17A MRSPs without Cannibalization

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
Total Cost	$205,611,405.06	$215,620,347.14	$224,848,513.18	$234,003,185.20	$243,260,714.64	$253,034,373.08	$260,821,778.64	$269,711,086.64
Range	233	233	233	233	233	233	233	233
Depth	3402	3514	3610	3708	3816	3922	4026	4126
% LRUs	100%	100%	100%	100%	100%	100%	100%	100%
% SRUs	0%	0%	0%	0%	0%	0%	0%	0%
% RR	100%	100%	100%	100%	100%	100%	100%	100%
% RRR	0%	0%	0%	0%	0%	0%	0%	0%

Table 22: One 24 C-17A MRSP without Cannibalization

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
Total Cost	$156,634,831.36	$164,725,735.75	$173,022,913.09	$181,470,954.69	$188,777,630.36	$196,634,521.04	$204,236,590.00	$211,956,869.24
Range	233	233	233	233	233	233	233	233
Depth	2306	2393	2478	2567	2646	2744	2824	2907
% LRUs	100%	100%	100%	100%	100%	100%	100%	100%
% SRUs	0%	0%	0%	0%	0%	0%	0%	0%
% RR	100%	100%	100%	100%	100%	100%	100%	100%
% RRR	0%	0%	0%	0%	0%	0%	0%	0%

The differences between the two kits are shown in Table 23.

Table 23: F-15C Differences without Cannibalization

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
Total Cost	$48,976,573.70	$50,894,611.39	$51,825,600.09	$52,532,230.51	$54,483,084.28	$56,399,852.04	$56,585,188.64	$57,754,217.40
Total Parts	1096	1121	1132	1141	1170	1178	1202	1219

The C-17A's very high DSO of 93.08 keeps the cost and asset totals high even with cannibalization, so turning off the cannibalization flag does not have much effect on the kit totals.

B-52H

Flying Hour Profile Scenarios. The B-52H is the bomber aircraft representative. The flying hour profile for the aircraft was derived from the default values found in the D087 file. The B-52H file has a surge period of 21 days and a sustainment period from 22 to 30 days. The sustainment period involves only slightly fewer flying hours than the surge period. Table 24 shows the eight scenarios used during the research for a 12-aircraft squadron.

Table 24: Flying Hour Profile for 12 B-52H

Day	Scen. 1	Scen. 2	Scen. 3	Scen. 4	Scen. 5	Scen. 6	Scen. 7	Scen. 8
1-21	34	44	54	64	74	84	94	104
22-30	32	42	52	62	72	82	92	102

A single B-52H flying in scenario 1 would fly 2.83 hours per day, while scenario 8 would result in each aircraft flying 8.67 hours or per day during the surge period. The values for scenario 4 are the D087 default values.

The flying hour profile values were doubled for the 24-aircraft scenarios. Table 25 shows the eight scenarios used for 24 aircraft:

Table 25: Flying Hour Profile for 24 B-52H

Day	Scen. 1	Scen. 2	Scen. 3	Scen. 4	Scen. 5	Scen. 6	Scen. 7	Scen. 8
1-21	68	88	108	128	148	168	188	208
22-30	64	84	104	124	144	164	184	204

The flying hour profiles result in the same sortie rates and hours as the 12-aircraft scenarios. The scenarios place the same demands on the aircraft, and thus the parts in the MRSPs, as two squadrons deploying with their own kits. The next section describes the ASM parameters unique to runs involving the B-52H.

ASM Parameters. For the first set of runs, the Fleet Size was set to 12 aircraft. The default DSO values from D087 were kept. The 1st Analysis day is day 5 and the DSO is

83.33%, or 10 available aircraft at the end of day 5. The 2nd Analysis day is day 30 with a DSO of 83%, or 9.96 aircraft available at the end of day 30. For the second set of runs with 24 aircraft, the DSO percentages remained the same, which changed the 1st Analysis availability goal to 20 aircraft and the 2nd Analysis day goal to 19.92. Cannibalization was set to "Full" for this set of runs.

Results with Cannibalization. The first data set to report is the case of two 12-aircraft squadrons deploying with their own MRSPs.

Table 26: Two 12 B-52H MRSPs

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
Total Cost	$55,603,684.38	$73,801,789.52	$91,279,628.96	$108,262,458.42	$125,255,913.90	$140,862,568.36	$157,852,609.58	$173,144,278.40
Range	232	234	234	234	234	234	234	234
Total Parts	1794	2172	2502	2816	3152	3452	3778	4048
% LRUs	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
% SRUs	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
% RR	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
% RRR	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

The next table shows the results of a custom MRSP designed to support all 24 aircraft:

Table 27: One 24 B-52H MRSP

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
Total Cost	$30,954,389.23	$46,177,275.49	$61,087,981.50	$75,824,571.78	$90,510,852.47	$104,639,332.74	$119,336,426.39	$134,069,997.49
Range	154	179	189	200	206	210	213	216
Total Parts	635	886	1139	1398	1645	1895	2146	2397
% LRUs	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
% SRUs	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
% RR	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
% RRR	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Note again that the only item changed between the two sets of runs (for 12 and 24 aircraft) is the number of aircraft assigned to the base. The flying hours were doubled, so each aircraft flies the same profile in each scenario. Table 27 shows the differences in total cost and total assets in the kits.

Table 28: B-52H Scenario Differences

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
Total Cost	$24,649,295.15	$27,624,514.03	$30,191,647.46	$32,437,886.64	$34,745,061.43	$36,223,235.62	$38,516,183.19	$39,074,280.91
Total Parts	1159	1286	1363	1418	1507	1557	1632	1651

The difference in total cost increases steadily from scenario 1 to scenario 8. Likewise, the number of parts in the kit increases as flying hours increase. The customized MRSP from the centralized storage area is cheaper and smaller than two kits from different bases in every scenario. To test the effects of cannibalization on the reduction in assets, the scenarios were run again with cannibalization turned off.

Results without Cannibalization. Tables 29 and 30 show the results after the cannibalization flag was switched to "none:"

Table 29: Two 12 B-52H MRSPs without Cannibalization

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
Total Cost	$85,101,265.94	$103,719,237.58	$121,704,174.62	$139,018,863.98	$156,077,188.68	$172,835,975.68	$189,533,000.08	$205,849,424.20
Range	234	235	235	235	235	235	235	235
Total Parts	2412	2782	3168	3500	3838	4160	4480	4768
% LRUs	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
% SRUs	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
% RR	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
% RRR	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Table 30: One 24 B-52H MRSP without Cannibalization

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
Total Cost	$65,955,450.75	$82,235,146.65	$98,023,726.43	$113,483,158.26	$128,722,331.75	$144,172,415.22	$158,673,674.44	$173,474,798.89
Range	235	235	235	235	235	235	235	235
Total Parts	1712	2020	2310	2593	2884	3155	3417	3689
% LRUs	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
% SRUs	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
% RR	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
% RRR	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

The differences between the two kits are shown in Table 31.

Table 31: B-52H Differences without Cannibalization

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
Total Cost	$19,145,815.19	$21,484,090.93	$23,680,448.19	$25,535,705.72	$27,354,856.93	$28,663,560.46	$30,859,325.64	$32,374,625.31
Total Parts	700	762	858	907	954	1005	1063	1079

As with the other aircraft, there is a sizeable savings gained with the development of a customized MRSP. While much larger than the standard MRSPs, the centralized management MRSPs computed without cannibalization still show a reduction in cost and footprint.

V. Conclusions and Recommendations

Overview

The need to reduce MRSP size and cost has never been greater. Air Force units are being tasked to support contingencies around the world, and the speed and range of airlift has made it the transport of choice. This thesis has examined a unique approach to reducing the spares requirements of deployed squadrons. This chapter will present the conclusions based on Chapter IV ASM analysis and examine some aspects of the research that may have affected the results. It concludes with suggestions for future research in this area.

Conclusions

Various scenarios involving multiple squadrons of aircraft from separate bases were used to test the concept of the centralized MRSP management facility. The idea that customizing the MRSPs could produce some sort of economies of scope was the basic premise behind this testing methodology. We found, for the MRSP files analyzed, there is a significant reduction in total cost and total assets needed to support the same flying profile requirements. Table 32 summarizes the percent decrease in cost and parts required for each aircraft.

Table 32: Percent Savings

Aircraft	% Cost	% Parts
F-15C	24.9	14.5
C-17A	27.5	35.2
B-52H	30.7	50.7

The average savings for the F-15C was $6.2 million and 142 parts over the eight scenarios. Savings for the C-17A averaged $60.7 million and 1,265 parts, and the B-52H averaged $32.9 million for 1,447 parts. These savings are quite significant, especially for the C-17A and B-52H, where every asset in the MRSP is an LRU. Many LRUs are expensive, and thus are in limited supply. These results show that establishment of a centralized facility will allow more LRUs to be pushed back out to the individual bases for operating stock, while still providing optimal support to deployed units supported by customized MRSPs.

Cannibalization is a major factor affecting the size and cost of the MRSPs. The ASM analysis shows the kit size increases when cannibalization is not allowed, but the savings resulting from centralized management are still present. Table 33 shows the percent savings of the analysis without cannibalization.

Table 33: Percent Savings without Cannibalization

Aircraft	% Cost	% Parts
F-15C	27.5	24.9
C-17A	22.6	30.8
B-52H	18.4	25.6

The average savings for the F-15C jumped to $16.2 million and 747 parts. The C-17A and B-52H showed slight drops in average savings at $53.7 million and 1,157 parts and $26.1 million at 916 parts, respectively. These results show that even without the aircraft availability gained by cannibalization a customized MRSP targeted for the exact number of deployed aircraft will yield the same support at a lower cost and size than would an MRSP managed in the traditional manner.

The F-15C FSL analysis shows an even more impressive result. Figure 14 shows a plot of the cost of four individual MRSPs and the plot of the FSL, or CIRF option.

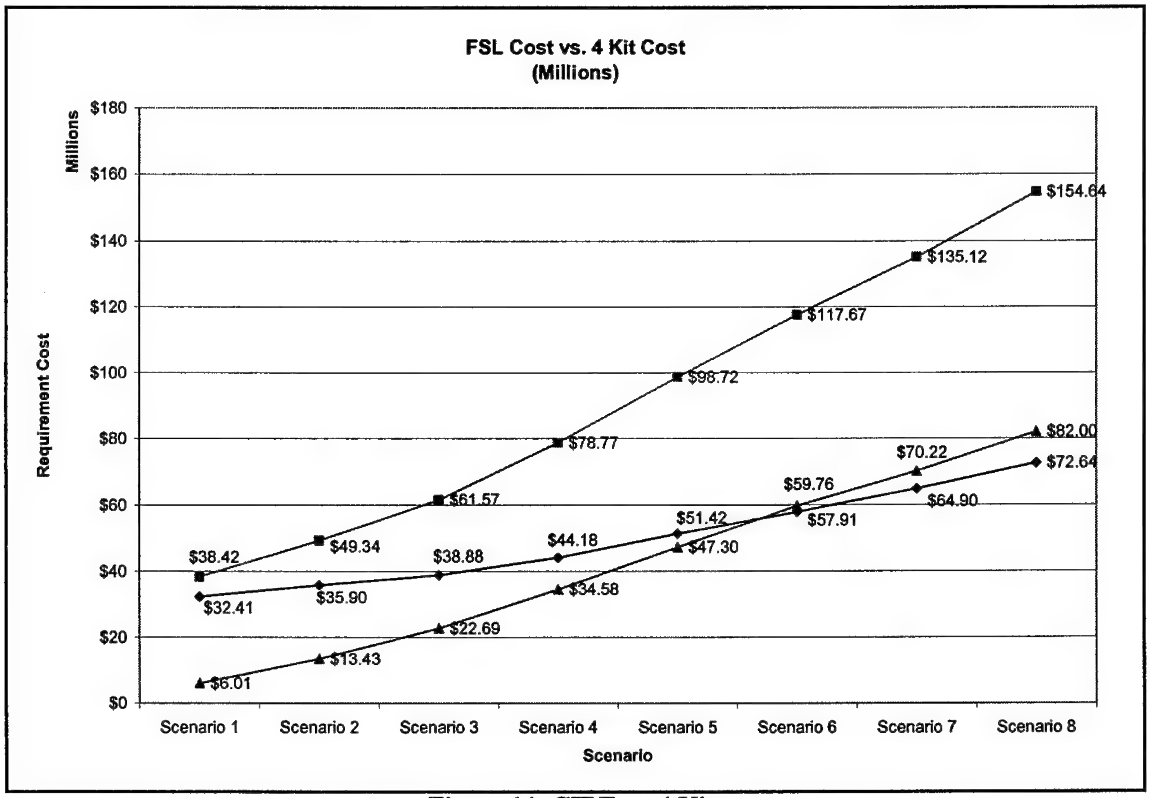

Figure 14: CIRF vs. 4 Kits

The triangle-marked line in Figure 14 is the difference between the two concepts. Around scenario 6, the cost to send four MRSPs to the FOL is more than twice as expensive as the establishment of a CIRF. Essentially, 96 aircraft could be supported by

two CIRFs for the cost of supporting only 48 aircraft with individual MRSPs. If a CIRF support concept is the expected support option for an AEF deployment, then a centralized MRSP management facility would be able to quickly build up and deploy the FOL and FSL packages for the entire region.

Factors Affecting Research

Perhaps the largest factor affecting the research was the use of raw D087 MRSP files for the starting point of the ASM runs. The F-15C data included LRUs and SRUs in both the RR and RRR types. ASM uses these values to determine what items can be repaired at the FSL and where to stock them. The C-17A and B-52H MRSP files did not have any items that the FSL option could evaluate, so no CIRF analysis could be accomplished on those aircraft. If military planners decide a CIRF support plan is an option for the C-17 and B-52, then different data files will be needed to run a proper analysis.

Another difficulty faced when using the FSL option was the undocumented nature of the option. The current version of ASM does not have a fully implemented FSL capability. As such, no information about exactly how the option functions was available. Agencies such as AFLMA and LMI are using the option, so it was believed to be useful to this research. Results should be viewed with the understanding that a final implementation may affect the outcome.

Unfortunately, not every flying hour scenario could be run in the limited amount of time the research was accomplished. Different surge and sustainment periods and even different DSO figures may show larger or smaller cost savings. The research did

include three general types of flying profiles: high surge/low sustainment (F-15C), steady-state (C-17A), and high surge/slightly lower sustainment (B-52H). In all cases, the custom MRSPs showed cost and size reductions. This leads us to suspect that different scenarios will show varying degrees of savings, but rarely, if ever, increased cost or size.

Future Research

This thesis examined a groundbreaking concept by supporting MRSPs through centralized management. No information about centralized MRSP management was found during the literature review. Conversations with other researchers and supply managers did not indicate that any research efforts had been aimed at exploring the options. As a result, there are numerous avenues for expanding the research in this area.

One area mentioned briefly in this thesis but not pursued was the savings in manpower costs and overhead by removing the WRM elements at the base supply level. Assets are constantly moving in and out of non-deployed MRSPs due to their higher priority level. This keeps a large percentage of personnel busy replenishing, inventorying, and issuing parts from the kits. In addition, the large containers used to house the assets consume valuable warehouse space. A real-world survey and cost analysis of the operating overhead required by such facilities would provide further insight into the viability of centralized MRSP management.

Another potential area for research is the examination of optimal placement of the centralized management facility (or facilities). Some discussions have suggested the facility be placed at the depot for whatever aircraft is being supported. Others suggest

regional centers based on geographic locations, such as east coast, west coast, USAFE, and PACAF. Another idea is to support multiple types of aircraft from one "superkit," where the airlift support comes through and picks up all the assets needed for aircraft deployed in the region of conflict.

This thesis was a theoretical exercise. While actual demand data was used for the runs, the scenarios used did not specify bases or actual real-world flying scenarios. Data on flying hours/mission profiles from real-world operations or exercises may be the next step in the research. In addition, use of actual base demand data and the number of real-world MRSPs for each aircraft type would contribute greatly to the understanding of the usefulness of the centralized concept.

Appendix A: Acronym Definitions

AEF	-- Aerospace Expeditionary Force
AFLMA	-- Air Force Logistics Management Agency
AFR	-- Air Force Regulation
APS	-- Afloat Planning System
ASM	--- Aircraft Sustainability Model
BRT	-- Base Repair Time
CIRF	-- Centralized Intermediate Repair Facility
DDR	-- Daily Demand Rate
DRT	-- Depot Repair Time
DSO	-- Direct Support Objective
EBO	-- Expected Backorders
EOQ	-- Economic Order Quantity
FOL	-- Forward Operating Location
FSL	-- Forward Support Location
GAO	-- General Accounting Office
LMI	-- Logistics Management Institute
LRU	-- Line-Replaceable Unit
METRIC	-- Multi-Echelon Technique for Recoverable Item Control
MOOTW	-- Military Operations Other Than Warfare
MRSP	-- Mobility Readiness Spares Package
MTW	-- Major Theater War
NOP	-- Non-Optimized

NMCS	-- Not Mission Capable-Supply
NRTS	-- Not Repairable This Station
OST	-- Order and Ship Time
PACAF	-- Pacific Air Forces
PBR	-- Percent Base Repair
PLQ	-- Pipeline Quantity
POS	-- Peacetime Operating Stock
QPA	-- Quantity Per Aircraft
RCQ	-- Repair Cycle Quantity
RET	-- Retrograde Time
RCT	-- Repair Cycle Time
RTS	-- Repaired This Station
SRU	-- Shop-Replaceable Unit
TLAM	-- Tomahawk Land Attack Missile
TSR	-- Total System Requirement
USAFE	-- US Air Forces Europe
WMP	-- War and Mobilization Plan

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14. ABSTRACT
Air Force supply doctrine requires the management of large numbers of spare parts in Mobility Readiness Spares Packages (MRSPs). The MRSPs are designed to support deployed aircraft for the first 30 days of a conflict, and can be quite large. When units from several bases deploy to the same operating location, they each bring their full MRSP. This results in a large logistics footprint that may be reduced by taking a system-level approach.

This thesis examined the impact of centralized MRSP management on kit size and cost. The Aircraft Sustainability Model (ASM) computer program was used to evaluate MRSPs for F-15C, C-17A, and B-52H aircraft deploying in both the traditional manner and with customized MRSPs from a centralized facility.

The results of the ASM analysis indicate there is a significant cost and size savings when MRSPs are customized for the total number of aircraft deployed to a region of conflict. While the size of the savings varied between aircraft and flying hour profiles, MRSPs from the centralized facility always provided the same level of support for less cost. The results show the Air Force could release spare parts in MRSPs and relieve the current spares shortages without degrading unit readiness.

15. SUBJECT TERMS
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